

Master thesis for the Master of Philosophy in Economics degree

Accounting for Norwegian-US real exchange rate changes

Kjersti Næss

January 2007

Department of Economics

University of Oslo



Preface

This thesis was written during my internship in the Research Department at Norges Bank (the Central Bank of Norway). I would like to express my gratitude to Norges Bank for providing me with economic funding and inspiring working conditions.

Several individuals have contributed to this thesis. I want to thank Tommy Sveen at Norges Bank for useful comments and discussions. I am also indebted to Leif Andreas Alendal for commenting several drafts and giving me invaluable support and encouragement throughout the process. Furthermore, I want to thank Øyvind Hagen at Statistics Norway for help in obtaining data. And finally, I want to express my gratitude to the most important contributor, my supervisor Ida Wolden Bache. Her insight and enthusiasm have been indispensable. All remaining errors are of course my and only my responsibility.

Contents

1	Introduction	1
2	Theory	3
2.1	The real exchange rate and the purchasing power parity theory	3
2.2	Factors causing variation in the relative price of traded goods	5
2.2.1	Sticky prices	5
2.2.2	Distribution costs	8
2.2.3	Differences in consumer preferences	10
2.3	Factors causing variation in the relative price of non-traded to traded goods	10
3	Real exchange rate decompositions	11
3.1	Engel (1999)	12
3.2	Burstein, Eichenbaum and Rebelo (2005)	14
3.3	The composition of imports and exports	17
4	Decomposing the Norwegian-US Real Exchange Rate	19
4.1	Data	19
4.1.1	Data sources and construction of variables	19
4.1.2	Unit root tests	20
4.2	Accounting for real exchange rate movements using retail prices	23
4.3	Accounting for real exchange rate movements using ‘at the dock’ prices . .	25
4.4	Accounting for real exchange rate movements using ‘at the dock’ prices of consumer goods	28
4.5	The importance of the distribution sector	30
5	Concluding remarks	31
A	Data	36
B	Method	38
B.1	Engel’s decomposition (section 4.2)	38
B.2	BER’s decomposition (section 4.3)	40
B.3	New decomposition (section 4.4)	41
C	Imports and exports by BEC in other countries	42
D	Matlab script	45

1 Introduction

A key stylised fact in international macroeconomics is that the real exchange rate is highly volatile and exhibits, at best, a slow rate of convergence towards a constant long-run equilibrium. Fluctuations in the real exchange rate may be brought about by deviations from the law of one price of traded goods or differential movements in the relative price of non-traded to traded goods in different countries. Traditionally, traded goods have been assumed to obey the law of one price, leaving changes in the relative price of non-traded to traded goods as the only source of real exchange rate fluctuations. The famous Balassa-Samuelson hypothesis¹ is an example of this. More recently, Stockman and Tesar (1995) and Fernández de Córdoba and Kehoe (2000) among others, have presented models where the real exchange rate is defined as the relative price of non-traded to traded goods, leaving no explanatory role for fluctuations in the relative price of traded goods.

However, a vast empirical literature has rejected the law of one price and found evidence of large fluctuations in the relative prices of traded goods across countries (see e.g. Knetter, 1993 and Engel and Rogers, 1996). Moreover, in a very influential paper, Engel (1999) claims that the relative price of non-traded to traded goods accounts for essentially none of the real exchange rate fluctuations. Specifically, he finds that over 90 percent of the fluctuations in the real exchange rate can be attributed to fluctuations in the relative price of traded goods for several OECD countries relative to the US. Chari, Kehoe and McGrattan (2002) find similar results. This evidence has been interpreted to imply that it is not important to distinguish between tradable and nontradable goods to understand the cyclical real exchange rate fluctuations (Burstein Eichenbaum and Rebelo, 2005) and has motivated a tremendous increase in research on models where traded goods prices account for all the movements in the real exchange rate, see e.g. Betts and Devereux (2000) and Chari, Kehoe and McGrattan (2002).

Burstein, Eichenbaum and Rebelo (2005) (henceforth referred to as BER) question the results obtained by Engel (1999) on the grounds that he uses consumer price indices to measure traded goods prices. The traded goods included in the consumer price index (CPI) are highly contaminated by non-traded components such as wholesale, distribution and retail services. In addition, goods specified as traded in the CPI may not actually be subject to trade. This may create a bias towards finding a greater importance of the traded goods sector in explaining real exchange rate fluctuations. To circumvent these possible problems BER use export price indices (EPI) and import price indices (IPI) to construct the relative price of traded goods. Using this measure they find that the non-traded component accounts for about half of the fluctuations in the real exchange rate, suggesting that the distinction between non-traded and traded goods is important for understanding real exchange rate fluctuations.

¹See Balassa (1961,1964) and Samuelson (1964).

In this thesis I argue that the approach taken by BER is likely to overestimate the importance of non-traded goods in explaining real exchange rate fluctuations. By using total import and export price indices they include several components not included in the CPI, e.g. raw materials such as raw oil and gas, and investment goods. For example, consumer goods accounted for only 6 percent of the Norwegian exports and about 23 percent of Norwegian imports in 2005. If these components have a higher tendency to obey the law of one price than consumer goods, their inclusion in the price index of traded goods will lead to an overestimation of the importance of non-traded goods in explaining real exchange rate fluctuations.

The contributions in this thesis are twofold: First, I decompose the fluctuations in the Norwegian-US real exchange rate using the methods proposed by Engel (1999) and BER. A main motivation for this analysis is to see whether Norway as a raw material based economy is different from the countries studied by those authors. Second, I decompose the real exchange rate using a new measure of traded goods prices based on import and export prices of consumer goods. This decomposition has been made possible by the fact that Statistics Norway recently published export and import price indices categorised by Broad Economic Categories (BEC). The advantage of using this measure compared to the measure used by BER is that it is possible to exclude all goods but consumer goods from the export and import price indices. Hence, I ensure that the goods used to calculate traded goods prices are similar to the ones included in the consumer price indices used to calculate the real exchange rate.

As expected, the share of real exchange rate fluctuations attributed to the relative price of non-traded to traded goods depends critically on the price measure used to calculate the relative price on traded goods. Not only does the distinction between retail and ‘at the dock’ prices matter, but also the composition of goods in the export and import price indices. Using retail prices, an upper bound of the importance of the relative price of non-traded to traded goods is found to be about 3 percent. By contrast, the upper bound is 65 percent when using aggregate export and import price indices. These results are similar to the results obtained by Engel (1999) and BER. However, the exclusion of all but consumer goods from the export and import price indices significantly lower the importance of the relative price of non-traded to traded goods, and the upper bound falls to 31 percent. Moreover, using a new real exchange rate decomposition I am able to explain most of the discrepancy between the results obtained using retail prices and ‘at the dock’ prices of consumer goods: The local distribution costs of traded goods are found to account for about 25 percent of the real exchange rate fluctuations. This suggests that it is important to distinguish between retail prices of traded goods and pure ‘at the dock’ prices of traded goods when accounting for real exchange rate fluctuations.

The thesis proceeds as follows. Section 2 decomposes the real exchange rate into a traded and a non-traded component and discusses factors that may cause variation in

the two components. Section 3 summarises the methods used and the results obtained by Engel (1999) and BER. In addition, I point out a possible weakness with the measure of traded goods prices used by BER. Next, section 4 presents the empirical evidence on the importance of the relative price of traded goods in explaining the fluctuations in the Norwegian-US real exchange rate from 1960 to 2006. Finally, section 5 concludes and summarises the thesis.

Most of the calculations in this thesis are conducted using MATLAB. I use EViews to test for stationarity of the variables.

2 Theory

Section 2.1 defines the real exchange rate and shows how the real exchange rate can be decomposed into a traded and a non-traded component. Next, section 2.2 discusses factors that may cause variation in the traded component. The factors considered are distribution costs and local currency price stickiness. Finally, section 2.3 presents the Balassa-Samuleson theory which explains variation in the non-traded component.

2.1 The real exchange rate and the purchasing power parity theory

The real exchange rate (RER) is defined as one country's aggregate price level relative to another country's, when prices are measured in a common currency. Measured in log-variables (which are denoted by lower-case letters throughout), the real exchange rate is

$$rer_t = s_t + p_t^* - p_t, \quad (1)$$

where s_t is the nominal exchange rate, p_t is the price level in the home country, and p_t^* is the price level in the foreign country. Different price measures are used to calculate the real exchange rate. The most common measures are: consumer price indices, producer price indices, and GDP deflators.

According to the purchasing power parity theory (PPP) the real exchange rate should be constant over time. The economic mechanism that should ensure this is arbitrage in the goods market. Absolute purchasing power parity (APPP) states that the relative price level between countries should equal the nominal exchange rate

$$s_t = p_t - p_t^*. \quad (2)$$

This is a strong assumption in most cases, and it has therefore been modified to incorporate the possibility of an everlasting, but fixed, price level difference between countries.

Relative PPP (RPPP) states that

$$\Delta s_t = \pi_t - \pi_t^*, \quad (3)$$

where Δs_t ² is the rate of nominal depreciation, and π_t and π_t^* denote the aggregate inflation in the home and foreign country, respectively.³ As argued by Rogoff (1996) neither the absolute nor the relative PPP is expected to hold in the short run, but many ‘... instinctively believe in some variant of purchasing power parity as an anchor for long-run real exchange rates.’ (Rogoff 1996, pp. 647). In order for the RPPP to hold in the long run any shocks to the real exchange rate can only have transitory effects, and the real exchange rate must be consistent with a stationary process.

There is a large literature testing for stationarity in real exchange rates using different methods and sample periods (for a survey of the literature, see e.g. Rogoff, 1996). Even though there is increasing evidence that the PPP holds in the very long run, the deviations from PPP are large and persistent. Consensus estimates of the half-life of a PPP deviation for industrial countries are in the range of 3 to 5 years (Rogoff, 1996).⁴ Akram (2006) tests for PPP between Norway and its main trading partners using quarterly data from the post Bretton Woods period 1972-1997. His findings indicate a half-life of only 1.5 years, which is remarkably low compared to estimates for other countries. The Norwegian government’s policy of preserving competitiveness and the system of centralized wage bargaining are seen as possible explanations.

When accounting for the fluctuations in the real exchange rate it is convenient to decompose the real exchange rate into a traded and a non-traded part. Following Engel (1999) a country’s price index may be expressed as a weighted geometric average of prices of traded goods $p_{T,t}$ and non-traded goods $p_{N,t}$

$$p_t = (1 - \gamma)p_{T,t} + \gamma p_{N,t}, \quad (4)$$

where γ is the share of non-traded goods in the price index. The foreign country’s index is defined the same way, with an asterisk representing the foreign country’s prices; that is

$$p_t^* = (1 - \gamma^*)p_{T,t}^* + \gamma^* p_{N,t}^*, \quad (5)$$

where γ^* is the share of non-traded goods in the foreign country’s price index.

Combining equations (4) and (5) with (1) enables us to decompose the CPI based rer_t

² Δ is the first difference operator, i.e. $\Delta x_t \equiv x_t - x_{t-1}$

³ First order log differences are approximately equal to the growth rates of the variable.

⁴ Imbs, Mumtaz, Ravn and Rey (2005) argue that previous estimates of the real exchange rate persistence are upward biased because of heterogeneity in the dynamics of disaggregated relative prices. When correcting for this heterogeneity, they present estimates indicating a half-life of 14 months.

into a traded part and a relative non-traded to traded part

$$rer_t^{cpi} = rer_t^T + rer_t^N, \quad (6)$$

where

$$rer_t^{cpi} = s_t + p_t^* - p_t,$$

$$rer_t^T = s_t + p_{T,t}^* - p_{T,t},$$

$$rer_t^N = \gamma^*(p_{N,t}^* - p_{T,t}^*) - \gamma(p_{N,t} - p_{T,t}).$$

This decomposition highlights two sources of fluctuations in the real exchange rate: deviations from the law of one price in traded goods, which cause the relative price of traded goods to fluctuate, and fluctuations in the relative price of non-traded to traded goods between countries. In addition, the share of non-traded goods in the price indices may vary.

2.2 Factors causing variation in the relative price of traded goods

An important factor in determining the fluctuations in relative prices of traded goods is the responsiveness of import prices to nominal exchange rate movements. Exchange rate pass-through is defined as the percentage import price response to a one percent change in the exchange rate. If the domestic currency depreciates by one percent and import prices increase by one percent, pass-through is said to be complete. Incomplete pass-through causes deviations from the law of one price and hence fluctuations in the relative price of traded goods.

Several factors influence the degree of exchange rate pass-through. Below I discuss two of the most important factors that have been considered in the literature: local currency price stickiness and distribution costs.

2.2.1 Sticky prices

When firms do not instantaneously adjust their prices in response to fluctuating exchange rates, the choice of currency in which to price exports becomes important. When exports are priced in the importer's currency, so-called local currency pricing (LCP), the import price is insulated from exchange rate movements in the short-run contributing to large fluctuations in the real exchange rate. If, however, the export price is set in the producer's currency, so-called producer currency pricing (PCP), export prices will respond fully to exchange rate movements implying complete exchange rate pass-through to import prices in the short-run. Several papers have also presented evidence of local currency pricing,

among these Giovannini (1988), Marston (1990), and Campa and Goldberg (2005). In the so-called ‘New Open Economy Macroeconomics’ literature, nominal rigidities have been assigned a central role as an explanation of the failure of the law of one price (Betts and Devereux, 1996, 2000).⁵

Following the framework of Rotemberg (1982), price stickiness can be modelled by price adjustment costs.⁶ If there are costs associated with changing prices, such as e.g. menu costs, a profit maximizing firm will take these costs into account. Assuming linear quadratic adjustment costs, the costs of changing the price increase more than proportionally with the size of the price change. Assume that the foreign firm sets the price in the importer’s currency (LCP), and let p_{t+j} denote the local currency price in period $t+j$. In the absence of adjustment costs the firm would like to set the price p_{t+j}^{TP} in period $t+j$, the ‘target price’. The firm has to weigh the costs of adjusting the price against the costs of deviating from the target price. Maximising profit with respect to prices is then equivalent to minimising the expected discounted value of a weighted average of adjustment costs and the costs of deviating from the target price

$$\min E_t \left[\sum_{j=0}^{\infty} \beta^j \left[(p_{t+j} - p_{t+j}^{TP})^2 + \eta (p_{t+j} - p_{t+j-1})^2 \right] \right], \quad (7)$$

where E_t denotes expectations conditional on information available at time t , β is the discount factor ($\beta \leq 1$), and η is the relative weight on the adjustment costs. The first order condition for p_t takes the form of an Euler equation

$$\Delta p_t = \beta E_t \Delta p_{t+1} - \frac{1}{\eta} (p_t - p_t^{TP}). \quad (8)$$

Assuming that the target price is the solution to the profit maximisation problem of a monopolistic firm, the target price is given as an optimal mark-up on marginal costs multiplied by the exchange rate (since the firm is setting the prices in the importer’s currency)

$$p_t^{TP} = s_t + \mu_t + mc_t, \quad (9)$$

where μ_t denotes the optimal mark-up in period t , and mc_t is the marginal cost in period t . Equation (8) can then be written as

$$\Delta p_t = \beta E_t \Delta p_{t+1} - \frac{1}{\eta} (p_t - (s_t + \mu_t + mc_t)). \quad (10)$$

The optimal price growth in the current period depends on expected future price growth,

⁵NOEM is a class of optimising dynamic stochastic general equilibrium models that incorporate imperfect competition and nominal rigidities. For a survey of the NOEM literature see e.g. Lane (2001).

⁶An alternative way of modelling price stickiness is provided by Calvo (1983)

which in turn is a function of expected future values of the target price, and the current deviation from the price target. The short-run effect of a change in the exchange rate on the import price is decreasing in the degree of stickiness, measured by the adjustment cost parameter η . The exchange rate pass-through to local currency import prices also depends on the expected persistence of the exchange rate shock. The longer a shock to the exchange rate is expected to last, the larger will the price change be today, and the pass-through will hence be larger.

Gopinath and Rigobon (2006) use import and export prices at the micro level to measure the degree of price stickiness. They present evidence of significant differences in the stickiness between ‘at the dock’ prices and retail prices. This has important implications for the choice of price measure when decomposing real exchange rate fluctuations. The stickiness ‘at the dock’ is in most cases more than twice as large as recent evidence on the stickiness in retail prices.⁷ This highlights the importance of distinguishing between prices of actual traded goods and prices of so-called tradable goods in the CPI. Gopinath and Rigobon point to differences in contracting relationships for prices ‘at the dock’ and retail prices and that goods entering the CPI may be produced mainly for local consumption as possible explanations for the difference in stickiness between ‘at the dock’ prices and retail prices. In contrast to standard modelling assumptions, both exports and imports are found to be sticky in dollars, suggesting a prevalence of local currency pricing in US import prices and producer currency pricing in US export prices. One can however argue that the US, with its size and position in the world trade, probably is an exception with regard to the currency of denominating exports and imports.

Boug, Cappelen and Eika (2005) estimate the degree of exchange rate pass-through to Norwegian prices. Their findings suggest that there is modest pass-through to consumer prices, but quite rapid pass-through to import prices. This is a common finding in macro data also for other countries (see e.g. Campa and Goldberg, 2005). This indicates that LCP is not very widely used in imports and that import price changes are not transmitted into consumer prices, which could reflect the importance of the distribution sector. The difference in the degree of pass-through to import prices and retail prices suggests that it is important to use the prices of actually traded goods when measuring traded goods prices, rather than the price of tradables at the retail level.

Nominal rigidities can only explain short-run deviations from the law of one price, however. Even though Giovannini (1988), Marston (1990), and Campa and Goldberg (2005) find evidence of LCP, they also find that imperfect exchange rate pass-through lasts longer than average stickiness, implying that nominal rigidities cannot be the only explanation of low exchange rate pass-through.

⁷Gopinath and Rigobon (2006) compare their results on ‘at the dock’ prices to the results obtained by Bils and Klenow (2004) using retail prices.

2.2.2 Distribution costs

Even if prices are fully flexible they do not necessarily obey the law of one price. Distribution costs, such as local transport and retail costs, may drive a wedge between import prices and retail prices that dampens the pass-through to retail prices and creates deviations from the law of one price in retail prices. This happens both because retail prices will respond less than proportionally to import price changes, since import prices only account for a share of the retail prices, and because the distributors may adjust their profit margins to absorb some of the exchange rate fluctuations. The concept of distributors actively trying to manage consumer prices is referred to as double marginalisation, see e.g. Hellerstein (2004).

According to Goldberg and Campa (2006), the distribution margins of consumption goods, defined as the sum of wholesale trade costs, retail trade costs, and transport costs, are approximately 40 percent of purchasers' prices both in the US and in Norway. This indicates the existence of a large wedge between wholesale prices and retail prices that may dampen the pass-through of exchange rate changes to retail prices even when prices are fully flexible. Distribution costs may thus explain long-run deviations from PPP. Goldberg and Campa also find that the distribution margins are sensitive to exchange rate changes, which is an indication of double marginalisation.

In addition to limiting the exchange rate pass-through to retail prices, cross-country differences in distribution costs may create differences in demand elasticities, and hence make it optimal for exporters to discriminate between markets. Such 'pricing to market' will create deviations from the law of one price 'at the docks'. Following Corsetti and Dedola (2005), this can be shown formally using a model with fully flexible prices and identical constant-elasticity preferences for consumption among consumers both at home and abroad. Firms producing tradable and nontradable goods are assumed to be monopolistic suppliers of one brand of goods only. The distribution of one tradable good requires a fixed number of units of a basket of nontradables. With identical constant-elasticity preferences for consumption the optimal price of non-traded goods is a constant mark-up on marginal costs

$$P_{N,t} = \frac{\theta}{\theta - 1} MC_{N,t}, \quad (11)$$

where θ is the constant elasticity of substitution between goods, and $MC_{N,t}$ denotes marginal costs in the non-traded sector. Assuming that the distribution sector operates under perfect competition (thus excluding the possibility of double marginalisation), the retail price of a representative brand h of a traded good expressed in the home currency is simply

$$P_t(h) = \overline{P}_t(h) + \lambda P_{N,t}, \quad (12)$$

where $\overline{P}_t(h)$ is the wholesale price, and λ denotes the units of nontradables needed to distribute one tradable good. Hence, the last term, $\lambda P_{N,t}$, represents the distribution costs in this model.

Assuming that international goods markets are segmented and hence, that firms are able to price discriminate, a representative Home firm producing tradables faces the following maximisation problem

$$Max_{\overline{P}_t(h), \overline{P}_t^*(h)} \left[\overline{P}_t(h) D_t(h) + S_t \overline{P}_t^*(h) D_t^*(h) - MC_{H,t} [D_t(h) + D_t^*(h)] \right], \quad (13)$$

where S_t is the nominal exchange rate, and variables referring to foreign firms and consumers are marked with an asterisk. $D(h)$ and $D^*(h)$ are the aggregate demand for product h at Home and abroad, defined as

$$D_t(h) = \left(\frac{\overline{P}_t(h) + \lambda P_{N,t}}{P_{H,t}} \right)^{-\theta} D_{H,t}, \quad (14)$$

$$D_t^*(h) = \left(\frac{\overline{P}_t^*(h) + \lambda P_{N,t}^*}{P_{H,t}^*} \right)^{-\theta} D_{H,t}^*, \quad (15)$$

where $P_{H,t}$ and $P_{H,t}^*$ are the utility-based price indices of Home produced tradables, and $D_{H,t}$ and $D_{H,t}^*$ denote the aggregate demand for Home produced tradables at Home and abroad, respectively. The first order conditions for solution to the maximisation problems yield the optimal wholesale prices of consumption good h , measured in Home's currency

$$\overline{P}_t(h) = \frac{\theta}{\theta - 1} \left(1 + \frac{\lambda}{\theta - 1} \frac{MC_{N,t}}{MC_{H,t}} \right) MC_{H,t}, \quad (16)$$

$$S_t \overline{P}_t^*(h) = \frac{\theta}{\theta - 1} \left(1 + \frac{\lambda}{\theta - 1} \frac{S_t MC_{N,t}^*}{MC_{H,t}} \right) MC_{H,t}, \quad (17)$$

where the terms in brackets represent the optimal state contingent mark-up. As long as there are asymmetries in relative productivity and/or factor prices in the distribution sector at Home and abroad, leading to different marginal costs, the optimal behaviour of the firms are to discriminate between markets or 'price to market'. The state contingent mark-ups are implicit functions of productivity shocks, monetary innovations and relative wages. Hence, the prices do not necessarily converge towards one another, at least not in the short to medium run, implying the possibility of persistent deviations from the law of one price.

The exchange rate pass-through to retail prices is imperfect in this model because the exchange rate pass-through is incomplete to prices 'at the dock', and because the distribution sector dampens the exchange rate pass-through to retail prices. The degree of exchange rate pass-through to import prices is incomplete because the optimal mark-

up depends negatively on the exporter's exchange rate, measured as Foreign currency per unit of Home currency. Exporters will thus absorb part of the exchange rate changes in their mark-ups. However, the distribution costs may also lead to increased exchange rate pass-through in this model: If non-traded goods prices are sensitive to exchange rate changes, e.g. due to a large import share, the price of non-traded goods will increase in response to a nominal depreciation, which in turn increases the distribution costs.

The importance of the distribution sector and its impact on the exchange rate pass-through to retail prices motivated BER to use prices at 'the dock' in their empirical research on real exchange rate fluctuations (see below).

2.2.3 Differences in consumer preferences

Aggregate traded goods prices may vary across countries even though the law of one price holds for each individual good. Differences in consumer preferences between countries will influence the composition of their consumption baskets, which in turn will affect the weights on these goods when calculating price indices. When the rate of inflation between traded goods differs, cross-country differences in consumption baskets may cause a long-lasting divergence in overall inflation rates, contributing to persistent deviations from PPP. Several models incorporate a so-called 'home bias' in the consumption price indices, i.e. the domestic consumption of traded goods contains more domestic goods than explained by the countries' world trade shares.⁸ This may cause deviations from PPP for traded goods even when prices are fully flexible.

2.3 Factors causing variation in the relative price of non-traded to traded goods

Traditionally, traded goods were assumed to obey the law of one price, implying that cross-country differences in the relative price of non-traded to traded goods were the only source of real exchange rate fluctuations. Early contributors to this theory are Cassel (1918) and Pigou (1923). One of the most famous applications of this classical theory is the Balassa-Samuelson hypothesis. Balassa (1961, 1964) and Samuelson (1964) argue that countries with relatively higher productivity levels in the traded sector compared to the non-traded sector tend to have a higher price level. Assuming that traded goods prices are given from abroad, i.e. obey the law of one price, a productivity increase in the traded sector will lead to higher wages. With perfect competition in the labour market, higher wages in the traded sector will transmit to the non-traded sector, causing a corresponding price increase of nontradables assuming no (or smaller) productivity growth here. One can argue that productivity growth in the non-traded sector is more limited than in the traded sector and hence that the differences in productivity between countries is due to

⁸See e.g. Galí and Monacelli (2005).

differences in the productivity in the traded goods sectors. If this is the case, then rich countries have become rich due to a productivity growth advantage in the traded sector. This leads to the famous Balassa-Samuelson hypothesis, that price levels tend to rise with a country's per capita income, and that long-run movements in the real exchange rate are driven largely by productivity growth differentials between the traded and non-traded sector.⁹ This theory focuses on movements in the relative price of non-traded to traded goods as the source of movements in the real exchange rate between countries in different development stages.

The empirical evidence on the Balassa-Samuelson hypothesis is mixed. In tests of PPP between industrialized countries, productivity differentials in the traded goods sector between countries are not found to have a significant effect (see e.g. Froot and Rogoff, 1991). However, in comparisons between countries at very different income levels there is empirical evidence supporting the Balassa-Samuelson hypothesis (Rogoff, 1996).

More recently, Stockman and Tesar (1995) incorporate a non-traded goods sector into an open-economy real business cycle model and explain real exchange rate fluctuations by sector specific shocks to consumer preferences and technology which cause fluctuations in the relative price of non-traded to traded goods across countries. The real exchange rate is defined as the relative price of non-traded to traded goods between countries, leaving no role for movements in the relative price of traded goods.

High government spending is another factor that may cause a real appreciation via the non-traded goods sector. Government spending has a tendency to be concentrated on non-traded goods, causing an increase in the relative price of non-traded to traded goods and hence, a real exchange rate appreciation.¹⁰ However, this can only explain short term deviations from PPP since the real exchange rate is only affected by demand shocks to the extent that capital and labour are not perfectly mobile across sectors. In the long-run, one expects that both capital and labour are perfectly mobile across sectors in which case the real exchange rate is determined by productivity and other supply factors (Rogoff, 1996).

3 Real exchange rate decompositions

Several previous studies have tried to decompose actual real exchange rate fluctuations into a traded and a nontraded component, see e.g. Engel (1999), Betts and Kehoe (2001, 2006) and Burstein, Eichenbaum and Rebelo (2005). The general conclusion from these studies is that traded goods prices do not seem to obey the law of one price, and hence, that a significant share of the observed real exchange rate fluctuations can be attributed

⁹See e.g. Obstfeld and Rogoff (1996) for a formal derivation of the Balassa-Samuelson proposition

¹⁰This may be particularly important for Norway, which due to its oil discoveries in the 1970s has been able to finance extensive public spending.

to movements in the relative price of traded goods between countries. However, whereas Engel finds that close to 100 percent of the fluctuations in the real exchange rate can be accounted for by movements in the relative price of traded goods, BER find that somewhere between 30 and 60 percent of the real exchange rate fluctuations can be accounted for by movements in the relative price of non-traded to traded goods between countries.

Sections 3.1 and 3.2 summarise the data and the methodology used by Engel and BER, respectively. In section 3.3 I argue that total export and import price indices are inaccurate measures of traded goods prices and motivate the use of ‘at the dock’ prices of consumer goods when measuring traded goods prices.

3.1 Engel (1999)

Engel (1999) studies real exchange rates between the United States and several OECD member countries. The analysis is performed using five different measures of nontraded goods prices: the consumer price index (CPI), output prices, personal consumption deflators, and the CPI relative to the producer price index (PPI). He also investigates the behaviour of the prices of a variety of marketing and distribution services relative to the general price level in Japan. Engel concludes that regardless of the price measure used, movements in the relative price of traded goods account for almost all of the movements in the real exchange rate. Below I focus on the results obtained for the CPI based real exchange rate. The results using the other price measures are very similar.

The real exchange rate is decomposed into a traded and a non-traded component using the decomposition summarised in equation (6). To measure the movements in the real exchange rate attributed to the traded goods component, Engel uses what he argues is a comprehensive measure of movements, the mean-squared error (MSE). For a variable x_t , the MSE is defined as the sum of the squared drift and the variance. The drift is calculated as the average change of the n^{th} difference of x_t

$$mean(x_t - x_{t-n}) = \frac{n}{T-1} (x_T - x_1), \quad (18)$$

where T is the sample size.¹¹ The variance is calculated using a small sample correction

11

$$\begin{aligned} mean(x_t - x_{t-n}) &= mean[(x_t - x_{t-1}) + (x_{t-1} - x_{t-2}) + \dots + (x_{t-n+1} - x_{t-n})] \\ &= n \times mean(\Delta x_t) \\ &= n \frac{(x_T - x_1)}{T-1} \end{aligned}$$

suggested by Cochrane (1988)¹²,

$$var(x_t - x_{t-n}) = \frac{T}{(T-n-1)(T-n)} \sum_{j=1}^{T-n} [x_{j+n} - x_j - mean(x_{j+n} - x_j)]^2. \quad (19)$$

The MSE of the n^{th} difference is then defined as

$$MSE(x_t - x_{t-n}) = var(x_t - x_{t-n}) + [mean(x_t - x_{t-n})]^2. \quad (20)$$

To measure the relative importance of the traded goods component, the MSE of rer^{cpi} is decomposed into MSE of rer^T and MSE of rer^N . Attributing half of the co-movements of the two components to the traded goods component, the fraction of total MSE accounted for by the traded component is

$$\begin{aligned} & \frac{MSE(rer_t^T - rer_{t-n}^T)}{MSE(rer_t^{cpi} - rer_{t-n}^{cpi})} \\ & + \frac{mean(rer_t^T - rer_{t-n}^T)mean(rer_t^N - rer_{t-n}^N)}{MSE(rer_t^{cpi} - rer_{t-n}^{cpi})} \\ & + \frac{cov(rer_t^T - rer_{t-n}^T, rer_t^N - rer_{t-n}^N)}{MSE(rer_t^{cpi} - rer_{t-n}^{cpi})}. \end{aligned} \quad (21)$$

However, Engel argues that, for all but one of the price measures, rer_t^T and rer_t^N are nearly uncorrelated in first differences.¹³ He therefore excludes the co-movements from the calculation of the MSE share of traded goods for these series. The MSE share of traded goods is then calculated as follows

$$\frac{MSE(rer_t^T - rer_{t-n}^T)}{MSE(rer_t^T - rer_{t-n}^T) + MSE(rer_t^N - rer_{t-n}^N)}. \quad (22)$$

Using monthly CPI data from January 1962 to December 1995, Engel decomposes the real exchange rate between the US and Canada, Germany, France, Italy, and Japan. The traded goods price index is measured as the sum of the price indices ‘food’ and ‘all goods less food’, and the non-traded goods price index is the sum of the price indices ‘shelter’ and ‘all services less shelter’.¹⁴ The MSE is calculated at all possible horizons with a

¹²Without the small-sample correction, the estimate of the variance will be downward biased in small samples. Engel argues that when using the MSE decomposition, a downward-biased measure of the variance will lead to an overestimation of the squared drift, since the variance will become unreasonably small for large n . Hence, he applies a small sample correction to make the variance estimator unbiased for small samples. A small sample correction is unnecessary in a variance decomposition, because it will cancel out in the numerator and the denominator (Engel, 1995).

¹³When considering producer price indices, the correlation is found to be significant, and the co-movements are included.

¹⁴OECD has unfortunately changed the subindices, so it is not possible to use the exact same categories

maximum lag of 406 periods. The MSE share of traded goods is found to be near one for all countries but Canada. If deviations from the law of one price in traded goods are transitory, one would expect a decreasing share as the horizon is increased. There is however no apparent decline in the share of the total MSE accounted for by the traded component as the horizon increases.

In addition to the MSE decomposition, Engel calculates the portion of the drift in the real exchange rate attributable to the drift in the traded goods component. The share of drift is calculated as follows

$$\frac{\text{mean}(rer_t^T - rer_{t-n}^T)}{\text{mean}(rer_t^T - rer_{t-n}^T) + \text{mean}(rer_t^N - rer_{t-n}^N)}. \quad (23)$$

The portions of the drift accounted for by the traded component in the five real exchange rates are given in table 1. To a large extent this measure maps the MSE share of traded goods. Canada has a remarkably low drift share compared to the other countries, as was the case for the MSE share.

Table 1. Share of drift attributable to the relative price of traded goods between the US and selected trading partners. Monthly logdata 1962-1995.

Country	Drift
Canada	0.485
France	0.993
Germany	0.996
Italy	0.857
Japan	0.999

Source: Engel (1999)

3.2 Burstein, Eichenbaum and Rebelo (2005)

BER argue that both consumer based and producer based price indices are inadequate measures of traded goods prices. The CPI for traded goods includes non-traded components like wholesale, distribution and retail services. In addition, several domestic goods classified as traded goods in the CPI are produced for local consumption only. PPI is less contaminated, but generally it excludes import prices, and for some countries it also excludes export prices. BER focus instead on prices ‘at the dock’ when measuring prices of tradable goods. Specifically, they use an equally geometric weighted average of export and import price indices to construct the price index of traded goods. The real exchange rate is defined using the aggregate CPI, and the non-traded component is calculated as the residual. The nominal exchange rate is a geometric-trade-weighted exchange rate.

on more recent data.

BER look at the US and 11 of its trading partners (Australia, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Sweden, and UK), using quarterly data from IMF's International Financial Statistics database (IFS) over the period 1971-2002.¹⁵ The sample variance of the CPI based real exchange rate is decomposed as

$$\text{var}(\text{rer}^{\text{cpi}}) = \text{var}(\text{rer}^T) + \text{var}(\text{rer}^N) + 2\text{cov}(\text{rer}^T, \text{rer}^N). \quad (24)$$

This measure takes account of the co-movements between the traded and non-traded components. The variance decomposition differs from the MSE decomposition to the extent that there is a common trend (drift) in the real exchange rate and one of its components. E.g., if there is a common trend in the real exchange rate and the relative price of traded goods, the MSE decomposition will assign a larger role to the traded component than the variance decomposition. To measure the importance of non-traded goods BER compute a lower and an upper bound based on the variance decomposition

$$L^N = \begin{cases} \frac{\text{var}(\text{rer}_t^N)}{\text{var}(\text{rer}_t^{\text{cpi}})} & \text{if } \text{cov}(\text{rer}_t^T, \text{rer}_t^N) \geq 0 \\ \frac{\text{var}(\text{rer}_t^N)}{\text{var}(\text{rer}_t^{\text{cpi}})} + \frac{2\text{cov}(\text{rer}_t^T, \text{rer}_t^N)}{\text{var}(\text{rer}_t^{\text{cpi}})} & \text{if } \text{cov}(\text{rer}_t^T, \text{rer}_t^N) \leq 0 \end{cases} \quad (25)$$

$$U^N = \begin{cases} \frac{\text{var}(\text{rer}_t^N)}{\text{var}(\text{rer}_t^{\text{cpi}})} + \frac{2\text{cov}(\text{rer}_t^T, \text{rer}_t^N)}{\text{var}(\text{rer}_t^{\text{cpi}})} & \text{if } \text{cov}(\text{rer}_t^T, \text{rer}_t^N) \geq 0 \\ \frac{\text{var}(\text{rer}_t^N)}{\text{var}(\text{rer}_t^{\text{cpi}})} & \text{if } \text{cov}(\text{rer}_t^T, \text{rer}_t^N) \leq 0 \end{cases} \quad (26)$$

The lower bound L^N is computed by attributing the covariance term to the fluctuations in the non-traded component when the covariance is negative and to the traded component when the estimated covariance is positive. Similarly, the upper bound U^N is computed by attributing the covariance term to the fluctuations in the non-traded component when the covariance is positive and to the traded component when the covariance is negative.

In contrast to Engel, BER find that the movements in the relative price of nontraded to traded goods across countries account for somewhere between 40 and 60 percent of the real exchange rate fluctuations for the most countries. The median of the results are reported in table 2.¹⁶

¹⁵BER isolate cyclical frequencies in the data by detrending the logarithmic series with a Hodrick-Prescott filter, using a smoothing parameter of 1600.

¹⁶The real exchange rate is defined as $RE R^{\text{cpi}} = P/SP^*$

Table 2. Quarterly logdata 1971Q1-2002Q3 (HP-Filtered).

	Median
Standard deviation	
$\text{std}(s)$	0.04
$\text{std}(rer^{cpi})/\text{std}(s)$	1.03
$\text{std}(rer^T)/\text{std}(s)$	0.62
Correlation with s	
rer^{cpi}	-0.96
rer^T	-0.69
Bounds on the importance of nontradables	
Lower bound	0.52
Upper bound	0.68

Source: Burstein, Eichenbaum and Rebelo (2005)

3.3 The composition of imports and exports

A potential weakness in the study by BER is the use of aggregate import and export price indices to measure traded goods prices. Both the export price index (EPI) and the import price index (IPI) include components that are not included in the CPI. In addition to consumer goods, the EPI and the IPI include raw materials, intermediate goods, and investment goods. These categories are likely to differ in the degree of exchange rate pass-through and the degree of deviation from the law of one price. For example, raw materials are more likely to obey the law of one price than consumer goods since many raw materials are homogenous goods that are traded in a single world commodity market. The inclusion of raw materials in the traded goods price index is likely to reduce the aggregate deviations from the law of one price in traded goods, and hence, cause an overestimation of the importance of non-traded goods. The degree of overestimation is likely to be particularly large in (small) raw material based economies like Norway. There is also evidence to suggest that the degree of price stickiness is higher for consumer goods than for intermediate goods. Measuring price stickiness ‘at the dock’ in the US, Gopinath and Rigobon (2006) find large heterogeneity across goods: the median price duration for ‘consumer’ goods is 9 months and 4.46 months for ‘industrial supplies and materials’.¹⁷

Figure 1 shows the composition of Norwegian and US imports and exports in 2005.¹⁸ The imports and exports are categorised by Broad Economic Categories (BEC), a UN classification system which categorises imports and exports by their end use, of which consumer goods is one category.¹⁹ As is apparent from the diagrams, consumer goods account for a relatively modest fraction of total trade: In 2005, consumer goods accounted for only 6 percent of Norwegian exports, and about 23 percent of Norwegian imports. In the US, consumer goods accounted for about 20 percent of total exports and 28 percent of total imports.²⁰ The category ‘fuels and lubricants’, consisting mainly of oil and gas, accounts for almost 70 percent of Norwegian exports. The inclusion of a highly traded good such as oil in the overall export and import price indices, as in BER, is likely to create a bias towards larger importance of the relative price of non-traded to traded goods in explaining real exchange rate movements between Norway and the US.

BER use an equally geometric weighted average of aggregate import and export price indices to compute an index of traded goods prices. However, total trade is not balanced: In 2005, Norway experienced a trade surplus of 309.2 NOK billion, and the US experienced a trade deficit of 716.73 USD billion. Trade in consumer goods is also far from balanced. In particular, according to Ganapolsky and Vilan (2005) the US has experienced a growing

¹⁷The category ‘food’ is an exception. The degree of stickiness in this category is found to be 3.63 months (Gopinath and Rigobon).

¹⁸Source: Statistics Norway and Bureau of Labor Statistics, U.S.

¹⁹BLS does not publish the data categorised by BEC, but with a similar end-use classification. Henceforth, I will refer to this US end-use classification as BEC, since the classification of goods is similar.

²⁰Food is included in the category ‘consumer goods’.

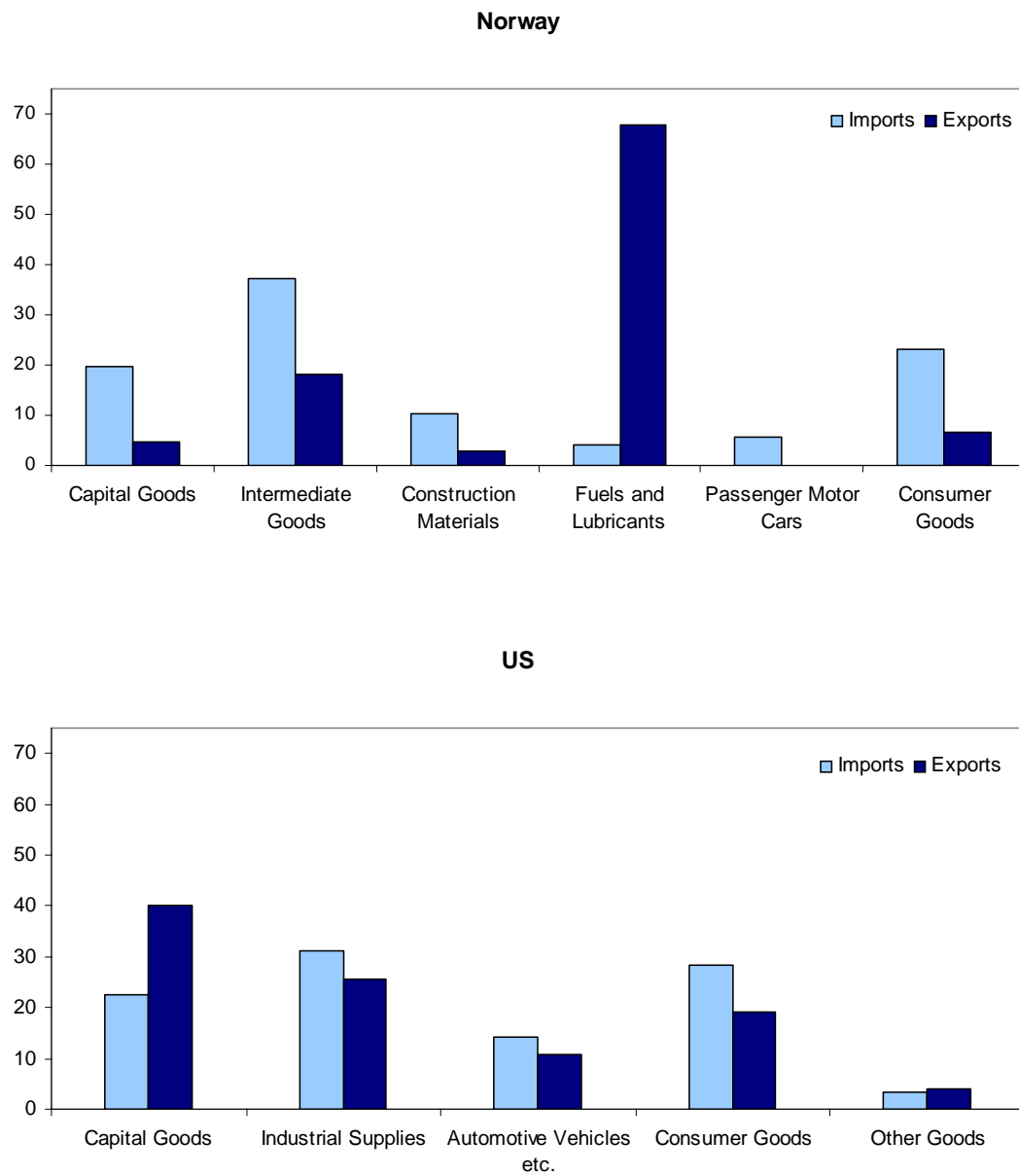


Figure 1. Imports and exports categorised by BEC. Percentage shares in 2005.

trade deficit in consumer goods since 1986. This indicates that it might be a problem to give equal weight to exports and imports when constructing an index of traded goods prices, in particular when the purpose is to account for the fluctuations in bilateral real exchange rates.

4 Decomposing the Norwegian-US Real Exchange Rate

In this section I decompose the real exchange rate between Norway and the US in the period from 1960 to 2006. The purpose is to account for the relative importance of movements in the relative price of traded goods in explaining the fluctuations in the real exchange rate. The real exchange rate is decomposed in two different ways using three different price measures. The price measures cover different time periods and different frequencies. To be able to compare the results from the different price measures 1989Q1-2006Q2 is used as a benchmark period.

Section 4.1 gives a detailed overview of the data and methods used. In addition, I report tests for stationarity of the variables used in the real exchange rate decomposition. The next three sections account for the importance of the relative price of traded goods in explaining real exchange rate fluctuations based on different measures of traded goods prices. In section 4.2, I use retail prices to measure traded goods prices, in section 4.3 I use total export and import price indices, and finally, in section 4.4, I use export and import prices of consumer goods. Section 4.5 combines the results from the previous three sections and discusses the importance of the distribution sector in explaining the real exchange rate fluctuations.

4.1 Data

4.1.1 Data sources and construction of variables

In the subsections below I will make use of different data series to measure traded and non-traded goods prices and different methods to construct the real exchange rate and its two components: the relative price of traded goods and the relative price of non-traded to traded goods. In this section I give a brief explanation of the methods and price measures used in each section. The subscript ‘retail’ denotes prices at the retail level and the subscript ‘dock’ denotes ‘at the dock’ prices. For a more detailed explanation of the price series and methods used, see appendix A and B, respectively.

In section 4.2, I follow Engel and decompose aggregate consumer price indices into a traded and a non-traded component adopting the convention of treating services as non-traded and commodities generally as traded. The real exchange rate (rer_{retail}^{cpi}) is measured as the sum of the relative price of traded goods (rer_{retail}^T) and the relative price of non-traded to traded goods (rer_{retail}^N) between Norway and the US. The traded and

non-traded goods prices are calculated using Norwegian data on CPI by delivery sector published by Statistics Norway, and detailed CPI for the US taken from the Bureau of Labor Statistics (BLS). It should be noted, however, that measuring the traded and the non-traded component of the real exchange rate involves classification challenges. Although some goods are clearly traded or non-traded, other goods are more difficult to classify. Some commodities are only produced for domestic consumers and are not really traded, but may be exposed to competition from abroad to such an extent that they should be regarded as traded. Other goods face only limited competition from abroad and should be treated as non-traded. To identify whether the good is actually traded, or to assess the degree of exposure to competition from abroad, may be difficult. Hence, deciding whether a good should be treated as traded or non-traded is difficult. Therefore, when the classification is particularly unclear, I perform some sensitivity analysis.

Following BER, in section 4.3 I measure the real exchange rate (rer^{cpi}) using aggregate CPI. The relative price of traded goods (rer_{dock}^T) is calculated using total export and import price indices. The relative price of non-traded to traded goods (rer^N) is calculated as the residual. The aggregate CPI, IPI, and EPI for Norway and the US are taken from IFS. Unless specified otherwise, imports and exports are given equal weight in the construction of the traded goods prices.²¹

In section 4.4, I again follow BER and use aggregate CPI to calculate the real exchange rate (rer^{cpi}) and let the relative price of non-traded to traded goods between Norway and the US be defined as the residual between the real exchange rate and the relative price of traded goods (rer_{dock}^T). However, the relative price of traded goods is now calculated using import and export prices on consumer goods only. The weights used to construct the index of traded goods prices are based on data for the Norwegian and US import and export shares of total trade for the period 1999-2005 and 2001-2006, respectively.²² The data series for import and export price indices and trade values for Norway categorised by BEC are from Statistics Norway.²³ Corresponding indices and values for the US are taken from BLS.

4.1.2 Unit root tests

This section reports the results of testing for stationarity of the variables. In general, it is of interest to test for a unit root in the real exchange rate, since the existence of a unit root will imply that a shock has a permanent effect on the real exchange rate, and thus that

²¹Imports and exports are given equal weight both due to lack of relevant available trade data and to enable comparison with BER who use equal weights.

²²Ideally, quarterly weights for the whole sample period should have been used to measure the relative importance of exports and imports. However, due to lack of available data, I was forced to use a shorter sample period when calculating average weights.

²³These data were published for the first time in the fourth quarter of 2005, with quarterly data from 2000 to 2006. In december 2006, the series was extended back to 1989.

the real exchange rate will not converge to a stationary long-run equilibrium as the RPPP theory predicts. In addition, whether or not the real exchange rate and its two components are stationary has implications for the method used to measure the importance of the relative price of traded goods in accounting for real exchange rate fluctuations. If the variables are non-stationary, the variance of the series will be unbounded, and the variance decomposition and the MSE decomposition will be inappropriate methods to account for the importance of the relative price of traded goods.

To test for unit roots I apply both the augmented Dickey Fuller (ADF) test and the so-called KPSS test introduced by Kwiatkowski, Phillips, Schmidt and Shin (1992), over the benchmark period 1989Q1-2006Q2. The ADF test has non-stationarity as its null hypothesis, while the KPSS test has stationarity as its null hypothesis. The tests are applied to the real and nominal exchange rate and the two components of the real exchange rate, the traded and the non-traded component as defined in section 2.1 above.

The results from the ADF test are presented in table 3. The numbers in brackets denote the lag-order. The test is conducted both on levels data and first differenced data, with and without a deterministic trend.²⁴ The significance of the test is marked by asterisks, where (*) and (**) denote rejection at the 5% and 1% significance levels, respectively.

Table 3. Augmented Dickey Fuller tests (variables in logs). 1989Q1-2006Q2.

Variable	Constant		Constant and trend	
	Level	1st difference	Level	1st difference
s_t	-1.6117 [1]	-6.8180 [0]**	-1.4896 [1]	-6.8074 [0]**
Retail prices				
rer_{retail}^{cpi}	-1.6741 [1]	-6.8179 [0]**	-1.6012 [1]	-6.8113 [0]**
rer_{retail}^T	-1.6981 [1]	-6.9379 [0]**	-1.8047 [1]	-6.9035 [0]**
rer_{retail}^N	-1.8523 [0]	-3.3208 [3]*	-1.2853 [2]	-7.8856 [1]**
Export and import prices				
rer^{cpi}	-1.6824 [1]	-6.8443 [0]**	-1.6287 [1]	-6.8310 [0]**
Total				
rer_{dock}^T	-0.7610 [3]	-4.2579 [2]**	-0.0655 [2]	-7.4552 [1]**
rer^N	-0.8682 [5]	-3.1163 [4]*	-2.9484 [4]	-3.2184 [4]
Consumer goods				
rer_{dock}^T	-1.5901 [3]	-4.2561 [4]**	-0.2785 [5]	-4.5767 [4]**
rer^N	-1.1937 [3]	-3.8564 [2]**	-2.5557 [4]	-3.8486 [2]*

²⁴The Akaike Information Criterion (AIC) is used to determine the lag order. The maximum lag-order is set to 5 when testing for a unit root in levels and 4 when testing for a unit root in the first-differenced series. For more details about the test, see e.g. Patterson (2000) pp. 238-241.

None of the variables are found to be stationary in levels. Hence, the MSE decomposition and the variance decomposition will be inappropriate for variables in levels. There are several ways to make the variables stationary. One approach is to difference the data. This is the approach taken by Engel and the approach taken below when applying Engel's method to decompose the real exchange rate fluctuations. As is evident from the table, the ADF test rejects the null hypothesis of a unit root for all the first-differenced series. Another approach to obtain stationarity is to detrend the series using a Hodrick-Prescott filter. This is the approach taken by BER and the approach I will take below when applying their method.

For the real exchange rate to be consistent with the RPPP theory, the real exchange rate should be stationary in levels. However, the real exchange rate is found to be non-stationary in levels, which indicates that the RPPP does not hold in the long run for the bilateral real exchange rate between Norway and the US.

The KPSS test differs from the ADF test in that the series are assumed to be stationary under the null hypothesis. The test statistics from the KPSS test are given in table 4. The number in brackets denotes the bandwidth.²⁵ The significance of the test is indicated with an asterisk, as above. Most of the results from the KPSS test are in accordance with the results from the ADF test, and the conclusion that the variables are non-stationary in levels is maintained.

Table 4. KPSS tests (variables in logs). 1989Q1-2006Q2.

Variable	Constant		Constant and trend	
	Level	1st difference	Level	1st difference
s_t	0.3189 [6]	0.1580 [2]	0.1427 [6]*	0.0924 [2]
Retail prices				
rer_{retail}^{cpi}	0.5115 [6]*	0.1466 [2]	0.1511 [6]*	0.0758 [2]
rer_{retail}^T	0.5193 [6]*	0.1191 [2]	0.1261 [6]	0.0810 [2]
rer_{retail}^N	0.2831 [6]	0.3937 [8]	0.2683 [6]**	0.1137 [21]
Export and import prices				
rer^{cpi}	0.4828 [6]*	0.1423 [2]	0.1486 [6]*	0.0780 [2]
Total indices				
rer_{dock}^T	0.2245 [6]	0.3554 [2]	0.2259 [6]**	0.0945 [5]
rer^N	0.7110 [6]*	0.1783 [3]	0.1683 [6]*	0.0473 [3]
Consumer goods				
rer_{dock}^T	0.2738 [6]	0.1719 [1]	0.1785 [6]*	0.0756 [2]
rer^N	0.6788 [6]*	0.0885 [2]	0.0920 [6]	0.0736 [2]

²⁵The Bartlett kernel is used as the spectral estimation method and the bandwidth is selected with the Newey-West method. For more details about the test, see e.g. Patterson (2000) pp. 268-270.

4.2 Accounting for real exchange rate movements using retail prices

This section accounts for the importance of the relative price of traded goods (rer_{retail}^T) in explaining real exchange rate (rer_{retail}^{cpi}) fluctuations using retail prices over the period 1983M1-2006M6.²⁶ In contrast to Engel, I exclude all co-movements between rer_t^T and rer_t^N from the MSE decomposition, also when the co-movements are significant. Engel arbitrarily assigns half of the co-movements to each component when the co-movements are found to be large. But, when the co-movements are found to be large, the treatment of the co-movements is particularly important and may have a large effect on the results. I therefore argue that arbitrarily assigning half of the co-movements to each component is too inaccurate. Instead, I present an upper and a lower bound based on the variance decomposition, which do account for the covariance between the variables.

Figure 2 plots the fraction of total MSE accounted for by the traded component in the Norwegian-US real exchange rate, where the horizon appears on the horizontal axis.²⁷ As is evident from the graph, the same striking result found by Engel (1999) also applies to the Norwegian-US real exchange rate: the MSE share of the traded goods component is close to one over all horizons, indicating that variation in the traded goods component is the main source of real exchange rate fluctuations. However, the last MSE shares are based on few observations and should be given limited attention.

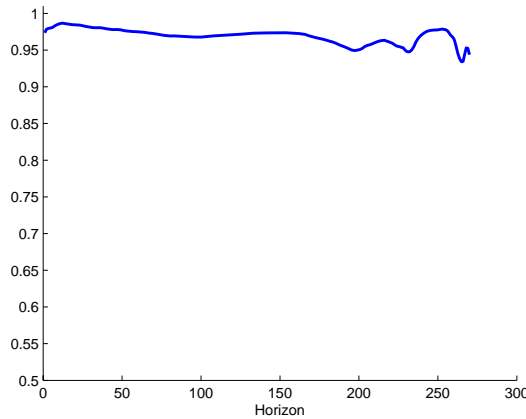


Figure 2. MSE share of traded goods. Norwegian-US real exchange rate. 1983M1-2006M6. Engel's decomposition.

²⁶The MATLAB script used to calculate the MSE decomposition and the variance decomposition is available in appendix D.

²⁷The correlation between the first differences of rer_{retail}^T and rer_{retail}^N is -0.07 for the whole sample period. $2Cov(rer_{retail,t}^T - rer_{retail,t-n}^T, rer_{retail,t}^N - rer_{retail,t-n}^N)$ is small relative to $Var(rer_{retail,t}^{cpi} - rer_{retail,t-n}^{cpi})$ for most n , specifically, 0.0141 in first-differenced data. Even though $mean(rer_{retail,t}^T - rer_{retail,t-n}^T)mean(rer_{retail,t}^N - rer_{retail,t-n}^N)$ is a large share of $mean(rer_{retail,t}^{cpi} - rer_{retail,t-n}^{cpi})^2$ for several n , the total squared drift is a small share of the MSE of the real exchange rate. Hence, the co-movements can be safely excluded from the MSE decomposition.

If the deviations from the law of one price in traded goods are explained by nominal rigidities, or other factors explaining short term deviations from the law of one price, the share of the MSE accounted for by the traded component should be declining as the horizon increases. However, there is no such decline apparent in the figure. This indicates persistent deviations from the law of one price in traded goods, contributing to large and persistent deviations from PPP.

In addition to measuring the relative MSE share, Engel calculates the share of the drift in rer_{retail}^{cpi} attributable to the drift in rer_{retail}^T (see section 3.1 above). The drift share is 0.9230 for the Norwegian-US real exchange rate, which again is similar to the European countries studied by Engel.

To ensure comparability with the results obtained using BER's method, I apply the variance decomposition used by BER to the data constructed using Engel's approach. The first two columns of table 5 present the summary statistics of the variables for the whole sample period and the benchmark period, respectively. The lower and upper bounds on the importance of non-traded goods for the whole sample period are 1.86 and 1.95 percent. These numbers are in accordance with the results obtained from the MSE decomposition. The upper bound is slightly higher for the benchmark period: the relative price of non-traded to traded goods accounts for about 3 percent of the real exchange rate fluctuations.

Table 5. Norwegian-US real exchange rate. Monthly and quarterly logdata (HP filtered).

	1983M1-2006M6	1989Q1-2006Q2	Alternative categorisation 1989Q1-2006Q2
Standard deviations			
$std(s)$	3.6960	6.1698	6.1698
$std(rer_{retail}^{cpi})/std(s)$	0.9963	0.9947	0.9925
$std(rer_{retail}^T)/std(s)$	0.9865	0.9791	0.9902
Correlation with s			
rer_{retail}^{cpi}	0.9916	0.9950	0.9952
rer_{retail}^T	0.9852	0.9923	0.9833
Correlation with rer_{retail}^T			
rer_{retail}^N	0.0032	0.0974	-0.0552
rer_{retail}^{cpi}	0.9906	0.9945	0.9899
Bounds on the importance of nontradables			
Lower bound	0.0186	0.0110	0.0045
Upper bound	0.0195	0.0312	0.0201

As is evident from the table, there is a very tight relationship between the nominal exchange rate, s_t , and the consumer based real exchange rate, rer_{retail}^{cpi} : both the correlation

and the relative standard deviation are high. This indicates that the nominal exchange rate is the main source of the real exchange rate fluctuations, and that aggregate consumer prices do not respond strongly to nominal exchange rate movements, thus causing deviations from PPP. A high correlation between nominal and real exchange rates is a ‘stylized fact’ in international macroeconomics.

The correlation between traded goods prices at the retail level, rer_{retail}^T , and the nominal exchange rate, s_t , is also high. The higher the correlation between these two components, the lower is the exchange rate pass-through to traded goods prices, and the larger are the deviations from the law of one price. A correlation coefficient of 0.9852 supports the view that traded goods do not obey the law of one price and thus contribute to large fluctuations in the real exchange rate.

As previously mentioned, some goods in the consumer price index are hard to classify as either traded or non-traded. Even though most agricultural products are easy to trade, they are not necessarily subject to trade. To what extent the Norwegian produced consumer goods are influenced by the world market is also difficult to measure. The third column reports results for an alternative categorisation of goods. Specifically, 50 percent of Norwegian agricultural goods, and Norwegian produced consumer goods influenced by the world market due to a large import share in inputs, are regarded as non-traded. The results for this alternative categorisation are very similar to the results obtained using the benchmark categorisation.

4.3 Accounting for real exchange rate movements using ‘at the dock’ prices

In this section traded goods prices are measured using total export and import price indices, covering the period 1960Q1-2006Q2. The data thus cover both fixed and floating exchange rate regimes.²⁸ However, the potential problem with mixing data from different exchange rate regimes is likely to be smaller in the benchmark period 1989Q1-2006Q2 when the Norwegian currency was free to float against the US dollar.

The results of applying the same method as BER on Norwegian-US data are summarised in table 6. The first column refers to the whole sample period, while the second column reports the results for the benchmark period. BER use a trade-weighted average of prices and a trade-weighted nominal exchange rate to construct their statistics, so it is not possible to make a direct comparison with their results. However, the results using Norwegian data are similar to the median of the results reported by BER that were summarised in table 2 above. Over the whole sample period, the importance of the non-traded goods sector in explaining the fluctuations in the Norwegian-US real exchange rate

²⁸The Norwegian currency was pegged to the US dollar until the collapse of the Bretton Woods system in 1971. According to Mussa (1986), the real exchange rate tends to be more volatile in a floating exchange rate regime. The implications of mixing data from different regimes are unclear.

is found to lie between 45 and 54 percent. This is in sharp contrast to the results obtained using retail prices, which suggested that non-traded goods account for essentially none of the real exchange rate movements. Moreover, the relation between rer_{dock}^T and s_t is considerably weaker than when considering retail prices, indicating that the exchange rate pass-through is larger to ‘at the dock’ prices than to retail prices. This supports BER’s argument that retail prices of traded goods contain a large non-traded component which dampens the exchange rate pass-through and causes an overestimation of the deviations from the law of one price in traded goods prices.

Table 6. Norwegian-US real exchange rate. Quarterly logdata (HP filtered).

	Total		Trade weighted	Excluding oil
	1960Q1-2006Q2	1989Q1-2006Q2	1989Q1-2006Q2	1989Q1-2006Q2
Standard deviation				
$std(s)$	5.5555	6.1698	6.1698	6.1698
$std(rer^{cpi})/std(s)$	0.9966	0.9978	0.9978	0.9978
$std(rer_{dock}^T)/std(s)$	0.7417	0.8616	0.8639	0.8307
Correlation with s				
rer^{cpi}	0.9583	0.9958	0.9958	0.9958
rer_{dock}^T	0.7307	0.7220	0.6644	0.9421
Correlation with rer_{dock}^T				
rer^N	-0.0834	-0.2296	-0.2872	0.2582
rer^{cpi}	0.6831	0.6936	0.6339	0.9304
Bounds on the importance of nontradables				
Lower bound	0.4461	0.2543	0.2504	0.1439
Upper bound	0.5371	0.5478	0.6519	0.3069

Figure 3 plots the fraction of total MSE accounted for by the traded component for the whole period and the benchmark period.²⁹ The MSE shares of traded goods are roughly within the variance bounds presented in table 6. The MSE share of rer^{cpi} attributable to rer_{dock}^T is higher in the benchmark period than in the whole sample period, suggesting that deviations from the law of one price in traded goods prices are larger in more recent data. However, the co-movements are relatively large in the benchmark period, making the estimates more uncertain. This is also reflected in the variance decomposition, where the discrepancy between the upper and the lower bound is significantly larger in the benchmark period than in the overall sample period.

²⁹The correlation between rer_{dock}^T and rer_t^N in first difference is -0.29 for the whole sample period and -0.40 for the benchmark period. The co-movements could hence be of importance. I nevertheless choose to exclude the co-movements since they are accounted for in the variance decomposition.

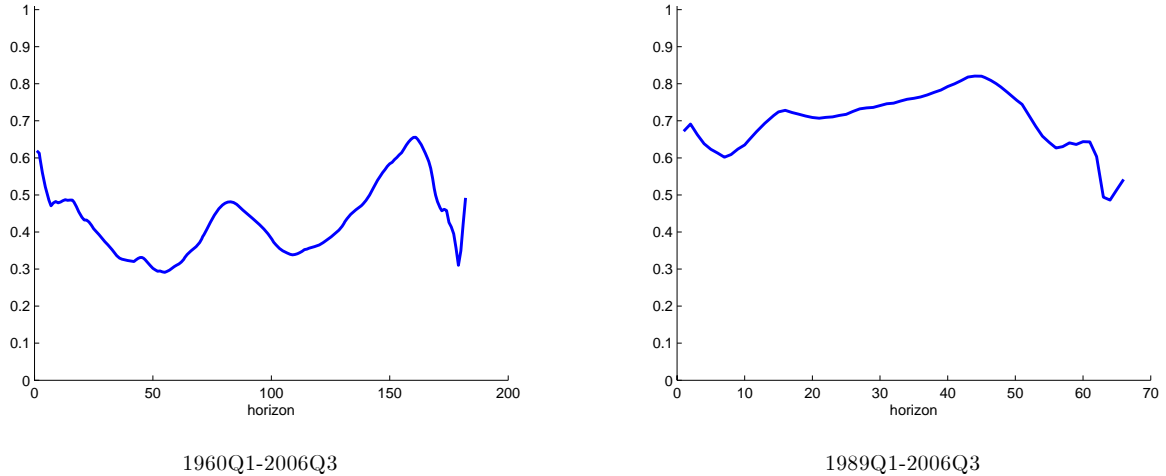


Figure 3. MSE share of traded goods. Norwegian-US real exchange rate.
Total EPI and IPI are used to measure traded goods prices.

As discussed in section 3.3 above, total trade is not necessarily balanced. The third column reports results when the weights on imports and exports are calculated using quarterly data on trade value. Applying more accurate weights on exports and imports increases the upper bound to 65 percent, thus attributing more of the fluctuations in rer^{cpi} to rer^N . A conjecture is that the Norwegian export prices are more likely to obey the law of one price, due to a large raw material share. Norway runs a significant trade surplus which means that export prices will be given a larger weight when using an import and export weighted measure of Norwegian traded goods prices. The relation between the relative price of traded goods and the nominal exchange rate is also found to be weaker, indicating smaller deviations from the law of one price in traded goods when the weight on export prices is larger.

As mentioned above, the IMF's IFS series include raw oil, gas and condensate. Excluding raw oil from the measure of traded goods substantially lowers the importance of non-traded goods. The last column of table 6 reports the results obtained when oil is excluded from the import and export aggregates. The upper bound falls from 65 percent to 31 percent. When excluding oil prices from the traded goods prices, the correlation between rer^{cpi} and s_t increases from 0.66 to 0.94, supporting the view that oil prices obey the law of one price to a much larger extent than other traded goods, and that the inclusion of oil prices in traded goods prices leads to an underestimation of the importance of movements in the relative price of traded goods in explaining movements in the CPI based real exchange rate.

Figure 4 plots the MSE share of traded goods when oil prices have been excluded from the Norwegian IPI and EPI and the US IPI.³⁰ When excluding oil prices, the MSE of

³⁰The correlation between rer_{dock}^T and rer_t^N is 0.03 in first differenced data, when oil prices have been excluded from traded goods prices. The relative covariance is 0.0197 in first-differenced data. Hence, the co-movements can be safely excluded from the MSE analysis.

the real exchange rate attributable to the MSE of the traded goods component increases significantly. Up to a horizon of about 15 years, the MSE share of the traded component is above 80 percent. Hence, the inclusion of oil in BER's measure of traded goods may to a large extent explain the divergence between the results found by Engel and BER. However, there are still several goods included in the traded goods aggregate that may be different from consumer goods with regard to the degree of exchange rate pass-through and deviations from the law of one price. In the next section I will therefore consider a decomposition that uses import and export prices of consumer goods to measure traded goods prices.

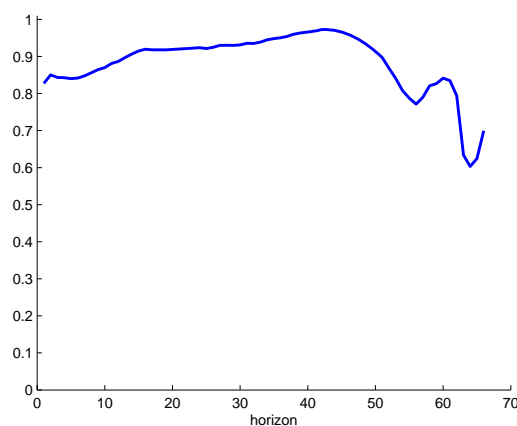


Figure 4. MSE share of traded goods. Norwegian-US real exchange rate. 1989Q1-2006Q2. Oil prices have been excluded from EPI and IPI.

4.4 Accounting for real exchange rate movements using ‘at the dock’ prices of consumer goods

In this section, export and import price indices of consumer goods are used to measure the relative price of traded goods. As argued above, the use of total export and import price indices to measure traded goods prices is likely to imply that the importance of non-traded goods will be overestimated. The statistical results presented in table 7 support this view. The upper bound on the importance of non-traded goods has decreased from 65 percent to 30 percent when excluding all goods but consumer goods in the calculations of traded goods prices. Moreover, the correlation between the nominal exchange rate, s_t , and the relative price of traded goods, rer_{dock}^T , has increased from 0.66 to 0.90. A higher correlation coefficient is consistent with lower degree of exchange rate pass-through and larger deviations from the law of one price. Hence, these estimates indicate that there are considerably larger deviations from the law of one price for consumer goods ‘at the dock’ than for aggregate exports and imports. The use of total export and import price indices,

as in BER, will assign a too large role for the relative price of non-traded to traded goods in explaining the fluctuations in the real exchange rate.

Table 7. Norwegian-US real exchange rate. Quarterly logdata (HP-filtered).

	Consumer goods 1989Q1-2006Q2	Excl. passenger cars 1989Q1-2006Q2
Standard deviation		
$\text{std}(s)$	6.1698	6.1698
$\text{std}(rer^{cpi})/\text{std}(s)$	0.9978	0.9978
$\text{std}(rer_{dock}^T)/\text{std}(s)$	0.8291	0.8346
Correlation with s		
rer^{cpi}	0.9958	0.9958
rer_{dock}^T	0.8973	0.8734
Correlation with rer_{dock}^T		
rer^N	0.1367	0.0626
rer^{cpi}	0.8912	0.8676
Bounds on the importance of nontradables		
Lower bound	0.2093	0.2483
Upper bound	0.3096	0.3004

The MSE share of the real exchange rate accounted for by the relative price of traded goods is plotted in figure 5.³¹ Again, this supports the conclusion that BER overestimate the importance of the relative price of non-traded to traded goods. However, the MSE share of traded goods is still considerably lower than the MSE share obtained when using retail prices to calculate traded goods prices. This supports BER's argument that Engel overestimates the importance of the relative price of traded goods. The correlation coefficient between s_t and rer_{dock}^T is found to be 0.90, as opposed to 0.99 when retail prices was used to measure traded goods prices, see table 5. Hence, 'at the dock' prices of consumer goods are more influenced by exchange rate movements than retail prices, indicating a higher degree of exchange rate pass-through to 'at the dock' prices than to retail prices, thus supporting the findings of e.g., Boug, Cappelen and Eika (2005). This may indicate the importance of a distribution sector that dampens exchange rate pass-through to retail prices.

³¹The correlation between $rer_{dock,t}^T$ and rer_t^N is -0.11 in first difference. The importance of the covariance, $2Cov(rer_{dock,t}^T - rer_{dock,t-n}^T, rer_t^N - rer_{t-n}^N)$, relative to the total variance, $Var(rer_t^{cpi} - rer_{t-n}^{cpi})$, is small for most n , specifically, 0.09 in absolute value for first differenced data. The co-movements can hence safely be excluded from the MSE decomposition.

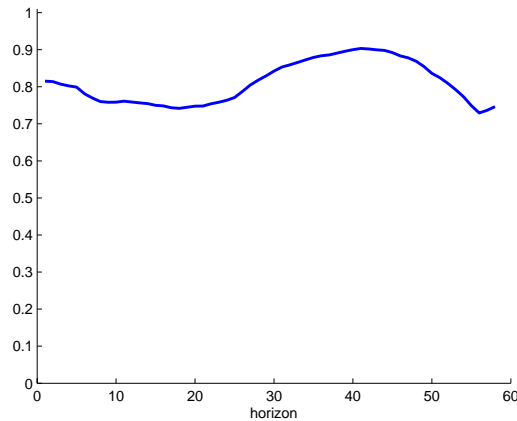


Figure 5. MSE share of traded goods. Norwegian-US real exchange rate. 1989Q1-2006Q2.
At the dock prices of consumer goods are used to calculate traded goods prices.

4.5 The importance of the distribution sector

At the end of his concluding remarks, Engel (1999, pp 531) brings up an important issue: ‘What systematic relationship is there between the price of a good at the port and the consumer outlet?’. The estimates reported above support the existence of a distribution sector that lowers the exchange rate pass-through to consumer prices. In order to distinguish between ‘at the dock’ prices and retail prices of traded goods, one may decompose the real exchange rate as follows³²

$$rer_t^{cpi} = rer_t^N + rer_t^B + rer_t^R, \quad (27)$$

where

$$rer_t^N = \gamma^*(p_{N,t}^* - p_{T,t}^*) - \gamma(p_{N,t} - p_{T,t}),$$

$$rer_t^B = s_t + \bar{p}_{T,t}^* - \bar{p}_{T,t},$$

$$rer_t^R = (p_{T,t}^* - \bar{p}_{T,t}^*) - (p_{T,t} - \bar{p}_{T,t}).$$

Here, variables with a bar denote ‘at the dock’ prices. The variable rer_t^B is the relative price of traded goods measured ‘at the dock’. The variable rer_t^R denotes the cross-country differential between ‘at the dock’ prices and retail prices, and can hence be interpreted as a measure of the relative distribution costs of traded goods. As above, the variable rer_t^N denotes the relative price of non-traded to traded goods between countries. The sum of rer_t^R and rer_t^B is equal to the relative price of traded goods, rer_t^T .

In this section, I account for the importance of the relative distribution costs in explaining real exchange rate fluctuations over the period 1989Q1-2006Q3, based on the

³²I am grateful to Ida W. Bache and Tommy Sveen for suggesting this decomposition.

decomposition in equation 27. Relative ‘at the dock’ prices of traded goods are calculated using export and import price indices of consumer goods, as in section 4.4. The consumer based real exchange rate are calculated using aggregate CPI. The relative price of non-traded to traded goods at retail level is calculated using detailed CPI, as in section 4.2. The relative distribution costs term is calculated as the residual. The MSE share of rer^{cpi} accounted for by the MSE of the relative distribution costs, rer_t^R , is plotted in figure 6 and is found to be somewhere between 20 to 30 percent.³³ This finding supports Engel’s conjecture that understanding the relationship between prices ‘at the dock’ and retail prices of traded goods is important for understanding real exchange rates.

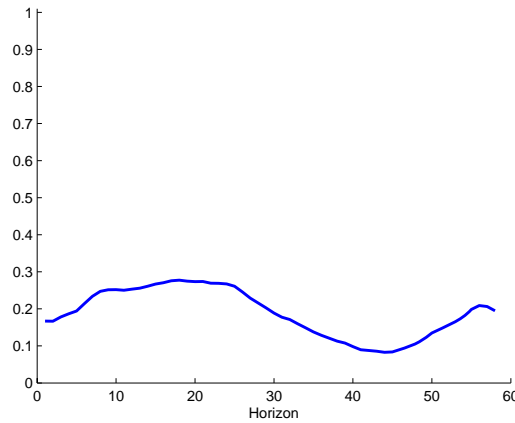


Figure 6. The MSE share of the distribution sector. Norwegian-US real exchange rate. 1989Q1-2006Q2.

The relative distribution cost term to a large extent explains the divergence between the results obtained using retail prices and ‘at the dock’ prices to measure traded goods prices. Hence, how one treats the distribution sector, either as being part of the non-traded sector or the traded sector, may have a large impact on the results. The fact that Engel implicitly treats the distribution sector as part of the traded sector and BER implicitly treat it as being part of the non-traded sector, may thus to a large extent explain the difference in the results obtained by those authors.

5 Concluding remarks

The main finding in this thesis is that the importance of the relative price of traded goods in explaining real exchange rate fluctuations depends critically on the measure of traded goods prices. When using retail prices to measure the relative price of traded goods, I find the same striking result as Engel (1999): The relative price of traded goods accounts for more than 95 percent of the real exchange rate fluctuations between Norway and the

³³All the co-movements between the variables are disregarded in this analysis.

US. The importance of the relative price of traded goods falls significantly, however, when prices of actually traded goods ‘at the dock’ are used to construct a measure of traded goods prices. As argued by BER, CPI prices of traded goods include a substantial share of non-traded goods and services, that may create a bias towards finding greater importance of the traded goods sector in explaining real exchange rate fluctuations.

However, even if export and import price indices only contain traded goods, there is large heterogeneity with respect to deviations from the law of one price among the different goods included. When excluding all but consumer goods from the export and import price indices, and hence ensuring that the goods included in the indices of traded goods are similar to the ones included in the CPI based real exchange rate, the upper bound on the importance of the non-traded component falls from 65 percent to 31 percent. This supports the argument that the use of total export and import price indices will lead to an underestimation of the deviations from the law of one price in traded goods, and hence, an underestimation of the importance of the relative price of traded goods prices in explaining real exchange rate fluctuations.

Distinguishing between retail prices and ‘at the dock’ prices of traded goods, I am able to account for the importance of relative distribution costs in explaining real exchange rate fluctuations. Movements in relative distribution costs were found to account for about 25 percent of the real exchange rate fluctuations, thus explaining most of the discrepancy between the results obtained using retail prices versus ‘at the dock’ prices of traded goods. Hence, there may not necessarily be any inconsistency between the results obtained by Engel (1999) and BER.

This thesis has solely focused on the Norwegian-US real exchange rate. However, there is reason to believe that excluding all but consumer goods from traded goods prices ‘at the dock’ has important implications not only for Norway. As evidenced in appendix C, trade in consumer goods accounts for a relatively modest share of the total trade in many countries. Extending the results in this thesis to a larger set of countries is an interesting topic for future research.

References

- [1] Akram, Q.F. (2006): “PPP in the medium run: The case of Norway”, *Journal of Macroeconomics* 28, 700-719.
- [2] Balassa, B. (1961): “Patterns of Industrial Growth”, *American Economic Review* 51, 394-397.
- [3] Balassa, B. (1964): “The Purchasing Power Parity Doctrine: A Reappraisal”, *The Journal of Political Economy* 72, 584-596.
- [4] Betts, C.M. and M.B Devereux (1996): “The exchange rate in a model of pricing-to-market”, *European Economic Review* 40, 1007-1021.
- [5] Betts, C.M. and M.B Devereux (2000): “Exchange Rate Dynamics in a Model of Pricing-to-Market”, *Journal of International Economics* 50, 215-244.
- [6] Betts, C.M. and T.J. Kehoe (2001): “Real Exchange Rate Movements and the Relative Price of non-traded Goods”, unpublished mimeo available at <http://www.econ.umn.edu/~tkehoe/papers/nontraded.pdf>
- [7] Betts, C.M. and T.J. Kehoe (2006): “U.S. Real Exchange Rate Fluctuations and Relative Price Fluctuations”, *Journal of Monetary Economics* 53, 1297-1326.
- [8] Bills, M. and P.J. Klenow (2004): “Some Evidence on the Importance of Sticky Prices”, *Journal of Political Economy* 102, 947-985.
- [9] Boug, P., Å. Cappelen and T. Eika (2005): “Exchange Rate Pass-through in a Small Open Economy. The Importance of the Distribution Sector”, Statistics Norway Discussion Paper, no. 429.
- [10] Burstein, A., M. Eichenbaum and S. Rebelo (2005): “The Importance of Nontradable goods Prices in Cyclical Real Exchange Rate Fluctuations”, NBER Working Paper 11699.
- [11] Campa, J.M. and L.S Goldberg (2005): “Exchange Rate Pass-Through into Import Prices”, *The Review of Economics and Statistics* 87, 679-690.
- [12] Calvo, G. (1983): “Staggered price setting in a utility-maximizing framework”, *Journal of Monetary Economics* 12, 383-398.
- [13] Cassel, G. (1918): “Abnormal Deviations in International Exchanges”, *Economic Journal* 28, 413-415.
- [14] Chari, V.V., P.J. Kehoe and E.R. McGrattan (2002): “Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?”, *Review of Economic Studies* 69, 533-563.

- [15] Cochrane, J.H. (1988): “How Big Is the Random Walk in GNP?”, *Journal of Political Economy* 96, 893-920.
- [16] Corsetti, G. and L. Dedola (2005): “A macroeconomic model of international price discrimination”, *Journal of International Economics* 67, 129-155.
- [17] Engel, C. (1995): “Accounting for U.S. Real Exchange-rate Changes ”, NBER Working Paper 5394.
- [18] Engel, C. (1999): “Accounting for U.S. Real Exchange-rate Changes”, *Journal of Political Economy* 107, 507-538.
- [19] Engel, C. and J.H. Rogers (1996): “How Wide Is the Border?”, *The American Economic Review* 86, 1112-1125.
- [20] Fernández de Córdoba, G. and T.J. Kehoe (2000): “Capital Flows and Real Exchange Rate Fluctuations Following Spain’s Entry into the European Community”, *Journal of International Economics* 51, 49-78.
- [21] Froot, K. and K. Rogoff (1991): “The EMS, the EMU, and the Transition to a Common Currency”, in S. Fisher and O.J. Blanchard (eds.), NBER Macroeconomics Annual 1991, the MIT Press, 269-317.
- [22] Galí, J. and T. Monacelli (2005): “Monetary Policy and Exchange Rate Volatility in a Small Open Economy”, *Review of Economic Studies* 72, 707-734.
- [23] Ganapolsky, E.J.J and D. Vilan (2005): “Buy foreign while you can: the cheap dollar and exchange rate pass-through”, Federal reserve Bank of Atlanta. Working Paper.
- [24] Giovanni, A. (1988): “Exchange Rates and Traded Good Prices”, *Journal of International Economics* 24, 45-68.
- [25] Goldberg, P.K. and M. Knetter (1997): “Goods Prices and Exchange Rates: What Have We Learned?”, *Journal of Economic Literature* 35, 1243-1272.
- [26] Goldberg, L.S. and J.M. Campa (2006): “Distribution Margins, Imported Inputs, and the Sensitivity of the CPI to Exchange Rates”, Staff Reports 247, Federal Reserve Bank of New York.
- [27] Gopinath, G. and R. Rigobon (2006): “Sticky Borders”, NBER Working Paper 12095.
- [28] Hellerstein, R. (2004): “Who Bears the Cost of a Change in the Exchange Rate? The Case of Imported Beer”, Staff Reports no. 179 (February), Federal Reserve Bank of New York.
- [29] Imbs J., H. Mumtaz, M. Ravn and H. Rey (2005): “PPP Strikes Back: Aggregation and the Real Exchange Rate”, *The Quarterly Journal of Economics* 120, 1-43.

-
- [30] Knetter, M. (1993): “International Comparisons of Pricing-to-Market Behavior”, *American Economic Review* 83, 473-486.
- [31] Kwiatkowski, D., P. Phillips, P. Schmidt and Y. Shin (1992): “Testing the null hypothesis of stationarity against the alternative of a unit root”, *Journal of Econometrics* 54, 159-178.
- [32] Lane, P.R. (2001): “The new open economy macroeconomics: A survey”, *Journal of International Economics* 54, 235-266.
- [33] Marston, R. (1990): “Pricing to market in Japanese Manufacturing”, *Journal of International Economics* 29, 217-237.
- [34] Mussa, M. (1986): “Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications”, *Carnegie-Rochester Ser. Public Policy* 25, 117-213.
- [35] Obstfeld, M. and K. Rogoff (1996): *Foundations of International Macroeconomics*. The MIT Press, London.
- [36] Patterson, K. (2000): *An Introduction to Applied Econometrics: A Time Series Approach*. Macmillan Press Ltd, London.
- [37] Pigou, A. (1923): “The Foreign Exchanges”, *Quarterly Journal of Economics* 37, 52-74.
- [38] Rogoff, K. (1996): “The Purchasing Power Parity Puzzle”, *Journal of Economic Literature* 34, 647-668.
- [39] Rotemberg, J. (1982): “Sticky Prices in the United States”, *The Journal of Political Economy* 90, 1187-1211.
- [40] Samuelson, P.A. (1964): “Theoretical Notes on Trade problems”, *The Review of Economics and Statistics* 46, 145-154.
- [41] Stockman, A.C. and L.L. Tesar (1995): “Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements”, *American Economic Review* 85, 168-185.

A Data

Table 8. Data used to measure US prices.

	Database	Series
Consumer prices		
Aggregate CPI	IMF IFS	(M./Q.)14264...ZF
CPI by end use		
All items	BLS	CUUR0000SA0
Commodities less food and beverages	BLS	CUUR0000SACL11
Food and beverages	BLS	CUUR0000SAF
Services less rent of shelter	BLS	CUUR0000SASL2RS
Rent of shelter	BLS	CUUR0000SAS2RS
Export and import prices		
Aggregate EPI	IMF IFS	Q.11176.X.ZF
Aggregate IPI	IMF IFS	Q.11176...ZF
EPI by end use		
Foods, Feeds and Beverages	BLS	EIUIQ0
Passenger cars, new and used	BLS	EIUIQ300
Consumer goods	BLS	EIUIQ4
IPI by end use		
Foods, Feeds and Beverages	BLS	EIUIR0
Passenger cars	BLS	EIUIR300
Consumer goods	BLS	EIUIR4
IPI excl. petroleum	BLS	EIUIREXPET
Trade values		
Aggregate export values [‡]	IMF IFS	Q.11190C.CZF
Aggregate import values [‡]	IMF IFS	Q.11198C.CZF
Export by end use	BC*	FT900, Annual Revisions
Import by end use	BC	FT900, Annual Revisions

* Bureau of the Census

[‡] seasonally adjusted

Table 9. Data used to measure Norwegian prices

	Database	Series
Consumer prices		
Aggregate CPI	IMF IFS	(M./Q.)11164...ZF
CPI by delivery sector	SN*	Subject 8, table 3362
Agricultural goods		L1
Fish products		L2
Other consumer goods produced in Norway		L3
Imported consumer goods		L4
Rent		L5
Other services		L6
Export and import prices		
Aggregate EPI ^{††}	IMF IFS	Q.14274...ZF
Aggregate IPI ^{††}	IMF IFS	Q.14275...ZF
EPI by BEC		
Consumer goods	NORMAP**	EKS.BEC_KONSUMVARER.IPR.Q.U
Passenger cars	NORMAP	EKS.BEC13.IPR.Q.U
IPI by BEC		
Consumer goods	NORMAP	IMP.BEC_KONSUMVARER.IPR.Q.U
Passenger cars	NORMAP	IMP.BEC13.IPR.Q.U
EPI excl. oil, gas and condensate	NORMAP	IMP.PTSOR.IPR.Q.U
IPI excl. oil	NORMAP	EKS.PTSORN.IPR.Q.U
Trade values		
Aggregate export values [†]	SN	Subject 9, table 3002
Aggregate import values [†]	SN	Subject 9, table 3002
Export by BEC		
Consumer goods	NORMAP	EKS.BEC_KONSUMVARER.VR.U
Passenger cars	NORMAP	EKS.BEC13.VR.U
Import by BEC		
Consumer goods		IMP.BEC_KONSUMVARER.VR.U
Passenger cars		EKS.BEC13.VR.U
Export excl. oil, gas and condensate	SN	Subject 9, table 3002
Import excl. oil	SN	Subject 9, table 3002
Exchange rates		
NOK/USD	OECD	MEI'NOR.CCUSMA02.ST.Q

* Statistics Norway

** NORMAP is a FAME database of business cycle indicators produced by Statistics Norway

† Excludes ships and platforms (oil drilling rigs and platforms are excluded from 1980 and onwards).

‡ based on unit value indices

B Method

B.1 Engel's decomposition (section 4.2)

Engel (1999) uses CPI series drawn from OECD's database. He specifies five categories: 'all items', 'all goods less food', 'food', 'services less rent', and 'rent'. Unfortunately, the OECD has changed the categories that are published, forcing me to use other data series when applying Engel's decomposition. For Norway, I use CPI by delivery sector. For the US, I use series for CPI categorised by end use.

The Norwegian data on CPI by delivery sector are classified into six main categories: 'agricultural products' (*agr*), 'fish products' (*fish*), 'other consumer goods produced in Norway', 'imported consumer goods' (*imp.goods*), 'rent', and 'other services' (*slr*). The category 'other consumer goods produced in Norway' contains three subcategories: 'other consumer goods produced in Norway, influenced by world market owing to large content of imported materials and raw-material prices fixed by the world market', 'other consumer goods produced in Norway, influenced by world market owing to competition from foreign countries', and 'other consumer goods produced in Norway, little influenced by world market prices'. The two first categories are generally treated as traded (*norw.prod.xposed*) while the latter is regarded as non-traded (*norw.prod.shelter*). Using monthly CPI weights for the different categories, published by Statistics Norway, the price indices of traded and non-traded goods are constructed as follows

$$\begin{aligned}
 p^T &= \left(\frac{\gamma_1}{\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4} \right) \times \text{agr} + \left(\frac{\gamma_2}{\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4} \right) \times \text{fish} \\
 &\quad + \left(\frac{\gamma_3}{\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4} \right) \times \text{norw.prod.xposed} + \left(\frac{\gamma_4}{\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4} \right) \times \text{imp.goods} \\
 \\
 p^N &= \left(\frac{\gamma_5}{1 - \gamma_1 - \gamma_2 - \gamma_3 - \gamma_4} \right) \times \text{norw.prod.shelter} + \left(\frac{\gamma_6}{1 - \gamma_1 - \gamma_2 - \gamma_3 - \gamma_4} \right) \times \text{slr} \\
 &\quad + \left(\frac{\gamma_7}{1 - \gamma_1 - \gamma_2 - \gamma_3 - \gamma_4} \right) \times \text{rent}
 \end{aligned}$$

where the variables are measured in logarithms. The average of the monthly weights for the different sectors are given in table 10.

Table 10. Norwegian weights on traded and non-traded categories. Sample average of monthly weights, 1983M1-2006M6.

Category		Weight
agr	γ_1	0.085
fish	γ_2	0.010
norw.prod.exposed	γ_3	0.184
imp.goods	γ_4	0.240
Total traded ($\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4$)	$(1 - \gamma)$	0.519
norw.prod.shelter	γ_5	0.109
slr	γ_6	0.224
r	γ_7	0.150
Total non-traded ($\gamma_5 + \gamma_6 + \gamma_7$)	γ	0.482

The US CPI by end use specifies almost the same five categories as used in Engel (1999): ‘all items’ (ai), ‘all commodities less food and beverages’ (aclfb), ‘food and beverages’ (fb), ‘services less rent’ (slr), and ‘rent’(r) Following Engel, I construct the US price indices of p^T and p^N , using the weights on the different categories, φ , from the following regression

$$\Delta(ai_t - r_t) = \varphi_1 \Delta(aclfb_t - r_t) + \varphi_2 \Delta(fb_t - r_t) + \varphi_3 \Delta(slr_t - r_t) + \epsilon_t.$$

The price indices of traded and non-traded goods are then calculated as

$$p^T = \left(\frac{\varphi_1}{\varphi_1 + \varphi_2}\right) \times aclfb + \left(\frac{\varphi_2}{\varphi_1 + \varphi_2}\right) \times fb,$$

$$p^N = \left(\frac{\varphi_3}{1 - \varphi_1 - \varphi_2}\right) \times slr + \left(\frac{1 - \varphi_1 - \varphi_2 - \varphi_3}{1 - \varphi_1 - \varphi_2}\right) \times r.$$

The weights on the different categories found from the regression analysis are summarised in table 11.

Table 11. US weights on traded and non-traded categories. Results of regression

Category		Weight
aclfb	φ_1	0.265
fb	φ_2	0.182
Total traded ($\varphi_1 + \varphi_2$)	$(1 - \gamma^*)$	0.447
slr	φ_3	0.277
r	φ_4	0.276
Total non-traded ($\varphi_3 + \varphi_4$)	γ^*	0.553

B.2 BER’s decomposition (section 4.3)

The real exchange rate, rer^{cpi} , is calculated using total CPI and the nominal exchange rate. The relative price of non-traded to traded goods, rer^N , is calculated as the residual between the real exchange rate and the relative price of non-traded to traded goods, rer_{dock}^T . The price of traded goods in each country is calculated as follows

$$p_{dock}^T = \alpha \log IPI_{total} + (1 - \alpha) \log EPI_{total},$$

where α is the import weight, and IPI_{total} and EPI_{total} are the total import and export price indices, respectively. Generally, trade is assumed to be balanced, and the export and import prices are given equal weight, i.e., $\alpha = 0.5$. However, I also calculate quarterly trade weights from trade value data for Norway and the US for the benchmark period, and for Norway when considering EPI and IPI excluding oil prices.

B.3 New decomposition (section 4.4)

As in section 4.3, the real exchange rate, rer^{cpi} , is calculated using total CPI and the nominal exchange rate, and the relative price of non-traded to traded goods, rer^N , is calculated as the residual between the real exchange rate and the relative price of non-traded to traded rer_{dock}^T . The price of traded goods in each country is calculated as follows

$$p_{dock}^T = \alpha \log IPI_{con} + (1 - \alpha) \log EPI_{con},$$

where

$$\log IPI_{con} = \tau_1^i \log IPI_{food} + \tau_2^i \log IPI_{pass.cars} + \tau_3^i \log IPI_{con.goods}$$

$$\log EPI_{con} = \tau_1^e \log EPI_{food} + \tau_2^e \log EPI_{pass.cars} + \tau_3^e \log EPI_{con.goods}.$$

Here, IPI_{con} and EPI_{con} denote export and import price indices of consumer goods, and τ_i is the weight on each category. The export and import weights on each category, and overall trade weights, are calculated using average trade values from the period 1999-2005 for Norway and 2001-2006 for the US. In the US trade value data, the sub-categories are not specified, with the consequence that there are no trade value data available for the category ‘Passenger cars, new and used’. To deal with this problem I assume that passenger cars account for 50 percent of the trade value of the category ‘Automotive Vehicles etc.’. The weights used in this section are summarised in table 12.

Table 12. Norwegian and US export and import shares.

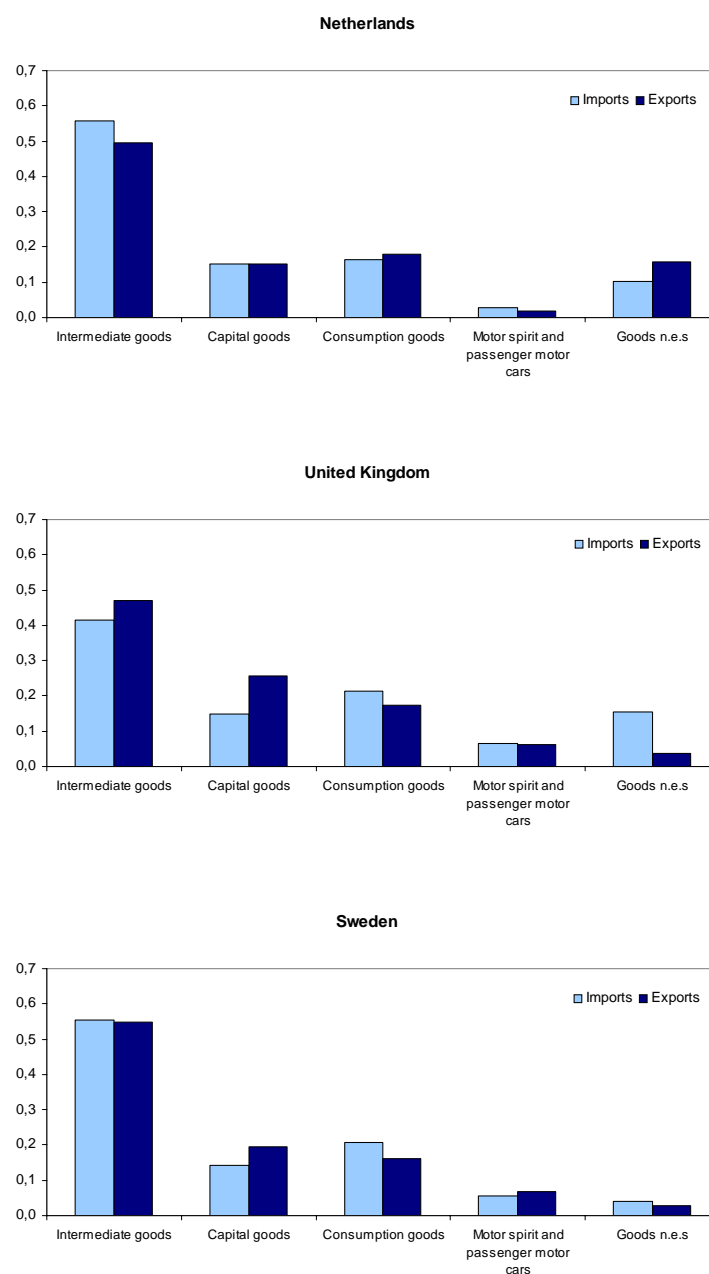
	Food τ_1^e, τ_1^i	Passenger cars τ_2^e, τ_2^i	Consumer goods τ_3^e, τ_3^i	Export and import weights $(1 - \alpha), \alpha$
Norway				
Export	*	0.00	1.00	0.32
Import	*	0.18	0.82	0.68
US				
Export	0.28	0.22	0.50	0.28
Import	0.11	0.21	0.68	0.72

* Food is included in ‘Consumer goods’

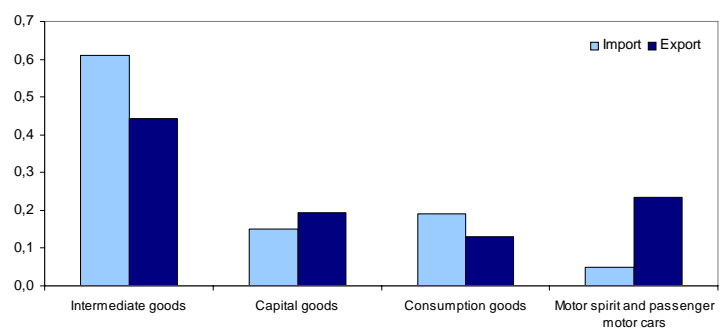
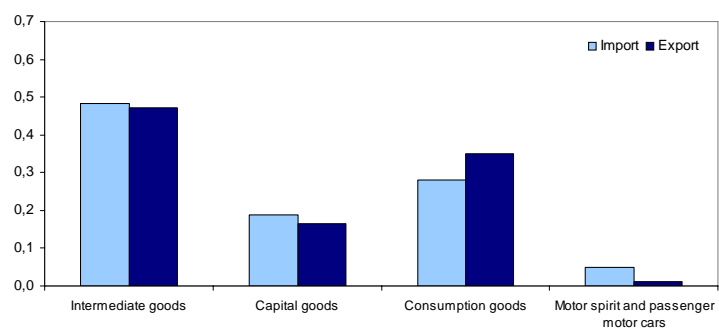
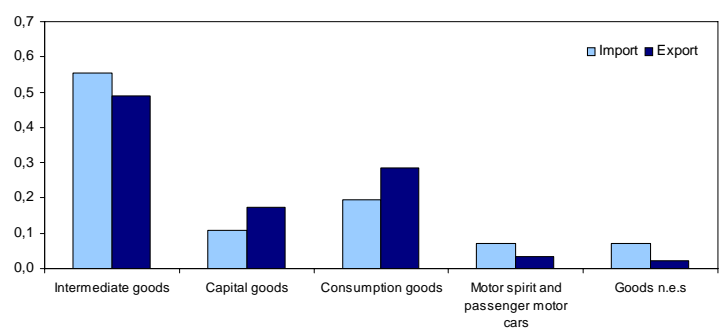
C Imports and exports by BEC in other countries

Trade by BEC in several members of the European Union and Australia are given in figure 7.³⁴

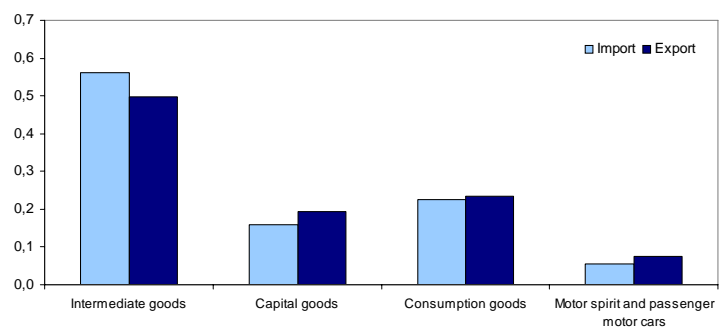
Figure 7. Imports and exports categorised by BEC. Percentage shares from January to August 2006.



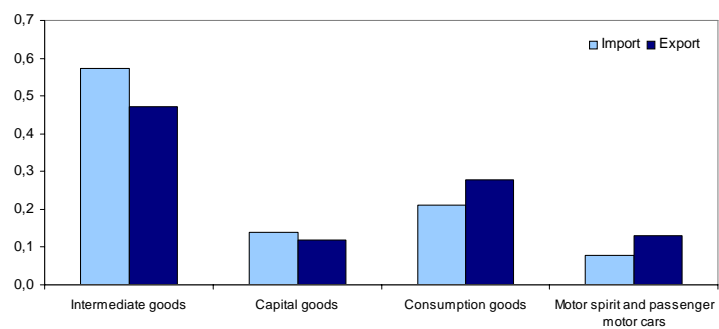
³⁴Source: Eurostat and Australian Bureau of Statistics

Germany**Denmark****Italy**

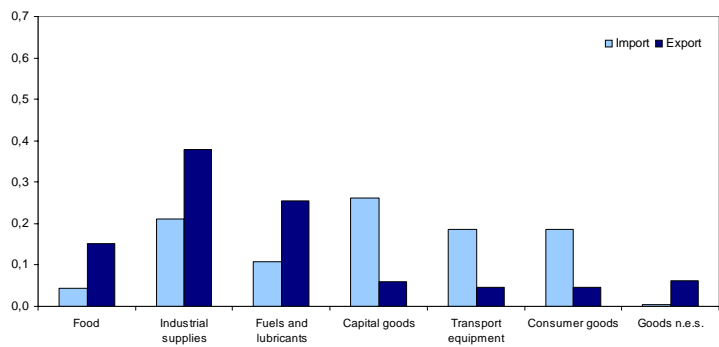
France



Spain



Australia



D Matlab script

```

%% Script to calculate the importance of the variation in the traded and
%% the nontraded component in explaining real exchange rate fluctuations

% x is the relative price of traded goods
% y is the relative price of nontraded to traded goods
% q is the consumer based real exchange rate

x=s+p_T_star-p_T;
y=vekt_non_star.*(p_N_star-p_T_star)-(vekt_non.*(p_N-p_T));

q=x+y;

%% Statistics with HP filter
% HP filter
q_hp=100*(q-(hpfilter(q,1600))); % 1600 because quarterly data
x_hp=100*(x-(hpfilter(x,1600)));
y_hp=100*(y-(hpfilter(y,1600)));
s_hp=100*(s-(hpfilter(s,1600)));

% Defining lower and upper limit
cov_x_y_hp=cov(x_hp,y_hp);
var_y_hp=var(y_hp);
var_q_hp=var(q_hp);

% Lower limit
if cov_x_y_hp(2,1) > 0;
    L_N=var_y_hp./var_q_hp;
else
    L_N=(var_y_hp./var_q_hp)+(cov_x_y_hp(2,1).*2/var_q_hp);
end

% Upper limit
if cov_x_y_hp(2,1) > 0;
    U_N=(var_y_hp./var_q_hp)+(cov_x_y_hp(2,1).*2/var_q_hp);
else
    U_N=var_y_hp./var_q_hp;
end

% Statistic output

```

```

statistics_hp=zeros(1,9);
statistics_hp(1,1)=std(s_hp);           % standard deviation of s
statistics_hp(1,2)=std(q_hp)./std(s_hp); % ratio of standard deviation(q,s)
statistics_hp(1,3)=std(x_hp)./std(s_hp); % ratio of standard deviation(x,s)
statistics_hp(1,4)=corr(q_hp,s_hp);     % correlation(q,s)
statistics_hp(1,5)=corr(x_hp,s_hp);     % correlation(x,s)
statistics_hp(1,6)=corr(x_hp,y_hp);     % correlation(x,y)
statistics_hp(1,7)=corr(x_hp,q_hp);     % correlation(x,q)
statistics_hp(1,8)=L_N;                 % lower bound
statistics_hp(1,9)=U_N;                 % upper bound

%% Mean squared error (MSE) share

qbar=(1/(T-1))*sum(q-[q(1);q(1:T-1)]); %E(q[t+1]-q[t])
xbar=(1/(T-1))*sum(x-[x(1);x(1:T-1)]); %E(x[t+1]-x[t])
ybar=(1/(T-1))*sum(y-[y(1);y(1:T-1)]); %E(y[t+1]-y[t])

m=zeros(T-12,12);

% loop for different lag (n)
for n=1:1:T-12
    qnbar=[zeros(n,1);(n*qbar*ones(T-n,1))]; % mean difference with n lags
    xnbar=[zeros(n,1);(n*xbar*ones(T-n,1))]; % mean difference with n lags
    ynbar=[zeros(n,1);(n*ybar*ones(T-n,1))]; % mean difference with n lags

    k=T/((T-n-1)*(T-n)); % A factor Engel uses to correct for small sample bias

    q_delvar=q-[q(1:n);q(1:T-n)]-qnbar; % difference minus expected difference
    x_delvar=x-[x(1:n);x(1:T-n)]-xnbar; % difference minus expected difference
    y_delvar=y-[y(1:n);y(1:T-n)]-ynbar; % difference minus expected difference

    m(n,2)=(q_delvar'*q_delvar).*k; % Variance q
    m(n,3)=(qbar.*n).*(qbar.*n); % (mean(q[t]-q[t-n]))^2
    m(n,1)=m(n,2)+m(n,3); % MSE q
    m(n,5)=(x_delvar'*x_delvar).*k; % Variance x
    m(n,6)=(xbar.*n).*(xbar.*n); % (mean(x[t]-x[t-n]))^2
    m(n,4)=m(n,5)+m(n,6); % MSE x
    m(n,8)=(y_delvar'*y_delvar).*k; % Variance y
    m(n,9)=(ybar.*n).*(ybar.*n); % (mean(y[t]-y[t-n]))^2
    m(n,7)=m(n,8)+m(n,9); % MSE y
    m(n,11)=(x_delvar'*y_delvar).*k; % covariance(x,y)

```

```

        m(n,12)=(xbar.*n).*(ybar.*n);           % mean(x[t]-x[t-n]))*mean(y[t]-y[t-n])
        m(n,10)=m(n,11)+m(n,12);               %
    end
    var_q=m(:,2);
    var_x=m(:,5);
    var_y=m(:,8);
    mse_q=m(:,1);
    mse_x=m(:,4);
    mse_y=m(:,7);
    mean_q=m(:,3);
    cov_xy=m(:,11);
    mean_xy=m(:,12);

    % Importance of the co-movements
    rel_cov=2*cov_xy./var_q;
    rel_mean=2*mean_xy./mean_q;

    % MSE decomposition
    mse_decomp=mse_x./(mse_x+mse_y);

    % Drift in q accounted for by drift in x
    mean_drift=(xbar.*xbar)./((xbar.*xbar)+(ybar.*ybar))

```